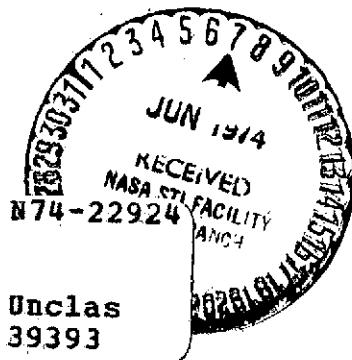


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CHARACTERISTICS PROGRAM (Advanced
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ADVANCED TECHNOLOGY LABORATORIES, INC.

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ATL TM 179

MANUAL FOR SOURCE FLOW
CHARACTERISTICS PROGRAM

By

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PREPARED FOR

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- UNDER

CONTRACT NAS1-12104

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TM 179
SECTION I
INTRODUCTION

The FORTRAN IV program described herein analyzes the nozzle for a hypersonic scramjet by a two dimensional second order characteristic procedure described in ATL TR 186, "A Source Flow Characteristic Technique for the Analysis of Scramjet Exhaust Flow Fields."

The program starts from the initial profile and marches along down-running characteristics until the final X station is reached. This process can be interrupted by "Change of Origin Profiles" in source flow cases. This is done by interpolating the characteristic data at the required axial station and setting up "F arrays" i.e., XF, YF, Then the program continues on down-running characteristics using the "F arrays" as an initial profile. These "F arrays" are computed for all flows at an X station that coincides with the cowl tip if there is a cowl in the flow field. If the flow is overexpanded at the cowl the program will invert the problem as described in ATL TR 186. When the shock reflects off the lower wall "F arrays" are again calculated and the computation continues with the problem inverted again until the final axial (X) station is attained.

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 SECTION II
DESCRIPTION OF INPUT

A. Input Format

<u>Card Number</u>	<u>Columns</u>	<u>Format</u>	<u>Description</u>
1	1-5	15	J1, type of flow (0-two dimensional, 1-axisymmetric)
	6-10	15	J2, coordinate exponent for line source system (0-two dimensional or axisymmetric, 1-line source)
	11-15	15	NPTS, number of data points on initial profile
	16-20	15	IEQ, chemistry indicator (0-frozen hydrogen-air chemistry, 1-equilibrium chemistry) NOTE: If IC ₀ WL = 1 then IEQ = 1.
	21-25	15	IC ₀ WL, external data indicator (1-overexpansion or underexpansion interaction calculations is required, 0-internal flow only). If IEQ = 0 then IC ₀ WL = 0.
	26-30	15	I ₀ VER, overexpansion indicator (0-flow definitely underexpanded, 1-flow overexpanded or marginal)
2	1-10	E10.0	*XB _P , ratio of axial coordinate of cowl at initial station to throat height
	11-20	E10.0	XB ₀ D, ratio of axial coordinate of lower wall at initial station to throat height
	21-30	E10.0	XC ₀ WL, ratio of axial coordinate of cowl trailing edge to throat height
	31-40	E10.0	RTH, throat height (ft.), scaling parameter L*
	41-50	E10.0	TEST, maximum allowable axial step size, used for computing upper boundary - typical value = .1

*(All length variables are nondimensionalized by RTH.)

<u>Card Number</u>	<u>Columns</u>	<u>Format</u>	<u>Description</u>
2	51-60	E10.0	XFINAL, ratio of final axial coordinate of run to throat height
	61-70	E10.0	XTJ1, ratio of axial coordinate of beginning of Cartesian region to throat height
3	1-10	E10.0	XSHFT, ratio of axial coordinate of moment axis to throat height
	11-20	E10.0	YSHFT, ratio of radial coordinate of moment axis to throat height
	21-30	E10.0	XTHX, initial thrust (lbs/RTH ²)
	31-40	E10.0	YLFT, initial lift (lbs/RTH ²)
4	1-5	15	NXXJ1, number of locations in source flow where a new initial profile is desired, maximum is 4, minimum is 1 (i.e. changes of origin, cowl station,...)
5	One of the following cards is necessary for each NXXJ1. If NXXJ1 equals 1 and 2-D flow, card 5a may be blank.		
5a	1-10	E10.0	XXJ1, ratio of axial coordinate of new initial profile to throat height
	11-20	E10.0	AXX, coefficients of polynomial describing a segment of lateral extent of the nozzle
	21-30	E10.0	BXX, for the equation $Z_L = AXX(X-X_1) + BXX$
	31-40	E10.0	XOR, ratio of axial coordinate of line source origin
5b	1-5	15	IFENCE, fence indicator (0-no fence; 1-supersonic fence exists)
	11-20	E10.0	AFENCE, coefficients of fence for the equation
	21-30	E10.0	BFENCE, $Y=AFENCE(X-X_{BP}) + BFENCE$
	31-40	E10.0	XFENCE, ratio of axial coordinate of fence on lower surface to throat radius
6	1-5	15	NUWSEG, number of polynomial segments describing the cowl (maximum is 3)
	6-10	15	NLWSEG, number of polynomial segments describing the lower wall (maximum is 3).

<u>Card Number</u>	<u>Columns</u>	<u>Format</u>	<u>Description</u>
7			One of the following cards is necessary for each cowl segment.
7a	1-10	E10.0	XXU(L), ratio of axial coordinate of beginning of "L th " segment of cowl to throat height
	11-20	E10.0	A, coefficients of the "L th " segment
	21-30	E10.0	B, of polynomial describing cowl for the equation
	31-40	E10.0	C, $Y=AX^2+BX+C$; $Y=Y/RTH$ & $X=X/RTH$
8			One of the following cards is necessary for each lower wall segment.
8a	1-10	E10.0	XXL(L), ratio of axial coordinate of beginning of "L th " segment of lower wall to throat height
	11-20	E10.0	A, coefficients of the "L th " segment
	21-30	E10.0	B, of polynomial describing lower wall for the equation
	31-40	E10.0	C, $Y=AX^2+BX+C$; $Y=Y/RTH$ & $X=X/RTH$
9	1-10	E10.0	EMINF, free stream or reference Mach number
	11-20	E10.0	TINF, free stream or reference temperature (0K)
	21-30	E10.0	WINF, free stream or reference molecular weight (1bs/1b-mole)
	31-40	E10.0	PINF, free stream or reference pressure (1bs/in ²)
10			Initial Profile - One of the following cards are required for each data point as described below. The program reads data points beginning at the lower wall (point #1) and proceeds to the cowl (point #NPTS).
10a	1-10	E10.0	X(I), ratio of axial coordinate of data point to throat height
	11-20	E10.0	Y(I), ratio of radial coordinate of data point to throat height
	21-30	E10.0	P(I), ratio of pressure at data point to free stream pressure
	31-40	E10.0	Q(I), ratio of velocity at data point to free stream velocity

<u>Card Number</u>	<u>Columns</u>	<u>Format</u>	<u>Description</u>
	41-50	E10.0	T(I), ratio of temperature at data point to free stream temperature
	51-60	E10.0	TH(I), flow inclination at data point (in radians)
	61-70	E10.0	R(I), fuel to air equivalence ratio (only necessary if IEQ=1)
11	Initial Mass Fractions - Same as card 10 above except for mass fractions at each data point. These cards are necessary only if IEQ=0.		
11a	1-10	E10.0	mass fraction of H
	11-20	E10.0	mass fraction of O
	21-30	E10.0	mass fraction of H ₂ O
	31-40	E10.0	mass fraction of H ₂
	41-50	E10.0	mass fraction of O ₂
	51-60	E10.0	mass fraction of OH
	61-70	E10.0	mass fraction of N ₂
12	This card is necessary only if ICOWL=1.		
	1-5	15	MM, number of points in Prandtl-Meyer fan including data downstream of shock (MM=9)
	11-20	E10.0	PM, ratio of pressure external to the cowl to free stream or reference pressure
	21-30	E10.0	QM, ratio of velocity external to the cowl to free stream or reference velocity
	31-40	E10.0	TM, ratio of temperature external to the cowl to free stream or reference temperature
	41-50	E10.0	THM, flow inclination external to the cowl (in radians)
	51-60	E10.0	RM, fuel to air ratio external to the cowl (only needed if IEQ=1)

B. Figures for Input

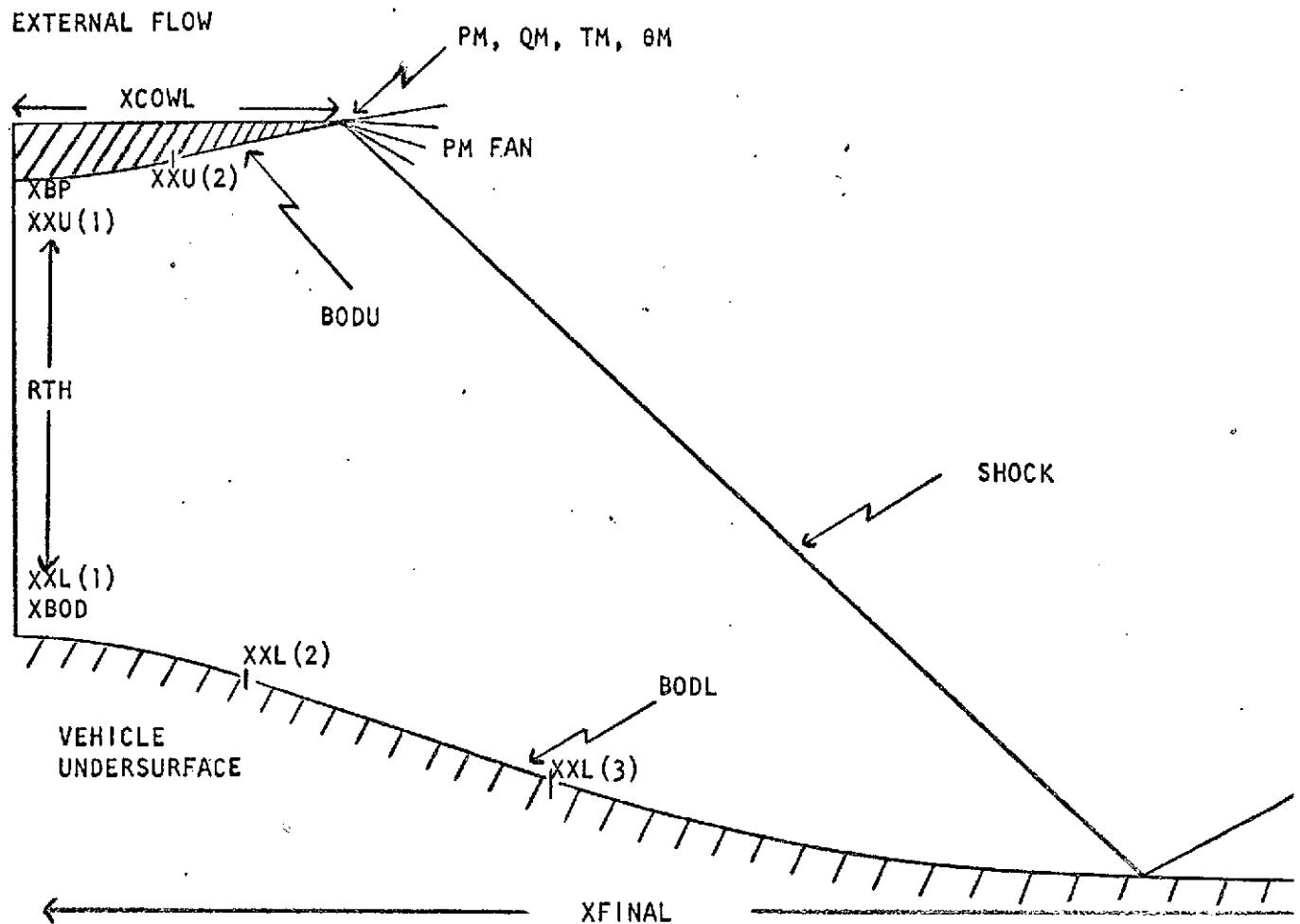


FIGURE #1. Definition of Physical Input Variables

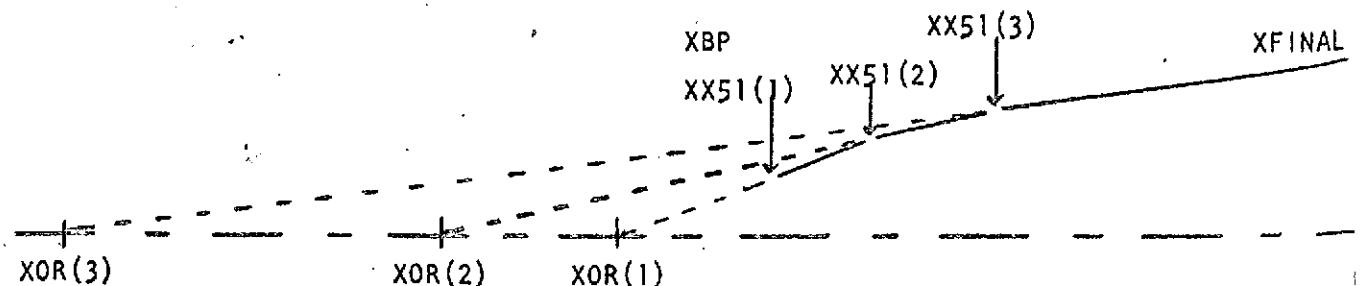


FIGURE #2. Definition of Change of Origin Variables

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SECTION III

DESCRIPTION OF OUTPUT

A. Output Format - The heading page contains program constants, line source coordinates and origin changes, upper and lower wall coordinates, free stream data at the cowl and infinity conditions. The program then prints the "initial profile," the data at selected points along down-running characteristics in the flow field and the running lift, thrust and pitching moment. The process continues until the input value for the final axial location is reached.

The above flow can be interrupted by "change of origin profiles" and a profile at the trailing edge of the cowl. If the flow is over-expanded at the cowl the output will switch to up-running characteristics from the lower wall to the contact surface and additional output covering the shock angle and external Mach number will be printed. When the shock reflects off the lower wall another profile will be printed and the run will proceed to the final axial location through down-running characteristics.

B. Identification of Output Variables

X - axial distance/throat height
Y - radial distance/throat height
Q - velocity/free stream velocity
T - temperature/free stream temperature
P - pressure/free stream pressure
TH - flow angle (radians)
EM - Mach number

ALP(1) = mass fraction of H
ALP(2) = mass fraction of O
ALP(3) = mass fraction of H_2O
ALP(4) = mass fraction of H_2
ALP(5) = mass fraction of O_2
ALP(6) = mass fraction of OH
ALP(7) = mass fraction of N_2

Frozen flow extra output is:

CPX - specific heat/free stream specific heat

W - molecular weight of mixture/free stream molecular weight

Equilibrium flow extra output is:

GAM - equilibrium isentropic exponent

PHI - fuel to air ratio

SECTION IV

SUBROUTINES AND FUNCTIONSA. Subroutines

<u>Name</u>	<u>Description</u>
1. INDATA	reads and prints initial data and computes infinity conditions
2. COEFF	sets thermodynamic coefficients as functions of temperature
3. ERROR	prints program statement number nearest selected errors and terminates computer run
4. BODL	locates axial and radial coordinates along lower vehicle surface
5. BODU	locates axial and radial coordinates along upper cowl surface
6. COWL	calculates shock jump relations and Prandtl-Meyer fan at cowl trailing edge for under-expanded flow
7. COWLO	computes contact points, shock points and shock angle at cowl trailing edge for over-expanded flow
8. SHOCK	calculates shock jump conditions
9. SHOCPT	computes shock angle by matching pressure from shock jump relations and pressure from characteristic relation on downstream side of shock
10. PANDW	makes pressure and frozen chemistry molecular weight or equilibrium chemistry fuel to air ratio
11. DRTEST	tests for dropping data points on free stream side of shock
12. PM	computes isentropic air expansion
13. ALL	calculates density, ratio of specific heats, Mach number, Mach angle, frozen flow specific heat, molecular weight and gas constant
14. THERMO	computes frozen flow specific heat, derivative of specific heat and enthalpy of each species from polynomial fits in temperature
15. XMASSS	computes mass flow correction factor
16. FM	computes mass function
17. PM1	computes flow properties for given Prandtl-Meyer turning

B. Functions

<u>Name</u>	<u>Description</u>
1. FT	calculates temperature at any data point in flow field
2. FH	computes static enthalpy at any point in flow field
3. FGAM	makes isentropic exponent and associated thermodynamic data at any point in flow field
4. RHEQ	computes equilibrium density
5. XM1	calculates $\tan(\theta + \mu)$ along up-running characteristic
6. XM2	calculates $\tan(\theta - \mu)$ along down-running characteristic
7. XM3	calculates $\tan(\theta)$ along streamline
8. F1	* A_1 or B_1 coefficient along up-running and down-running characteristics respectively
9. F2	* A_2 or B_2 coefficient along up-running and down-running characteristics respectively.

*Note: $p - \theta$ relationship along up-running characteristic:

$$A_1(p_C - p_A) + \theta_C - \theta_A + A_2(x_C - x_A) = 0$$

$p - \theta$ relationship along down-running characteristic:

$$B_1(p_C - p_B) - \theta_C + \theta_B + B_2(x_C - x_B) = 0$$

SECTION V

MACHINE CONTROL CONSIDERATIONS

1. Machine - program designed for CDC 6600.
2. Estimates for run.
 - a. Field length:
 - (1) compile - 65,000 octal locations
 - (2) load - 120,000 octal locations
 - (3) run - 100,000 octal locations
 - b. CP time: variable depending on number of points in initial profile and type of flow
 - c. 10: less than 100 octal seconds
 - d. Tapes or disks used:
 - (1) Tape 5 - card input
 - (2) Tape 6 - printed output
 - (3) no other tapes or disk files used
 - e. Printed output: as in CP time it is variable depending on case submitted.

SECTION IV

SAMPLE INPUT FOR SOURCE FLOW CASE 1B FROM ATL TR 186

0	1	41	1	1	0			
0.	0.		3.	1.	1.	.1		
0.	.5		0.		0.	0.		
2								
0.	.0875		1.		-7.			
3.	.0875		1.		-7.			
1	-.59		3.064		16.			
2	3							
0.	.1314		0.		1.			
0.4	0.		.1051		.979			
0.	-.5565		0.		0.			
0.4	0.		-.4452		.08905			
8.	.01019		-.6082		.741			
10.	232.3		28.96		.1603			
0.	0.		36.65		.929	10.1	0.	1.
0.	.025		36.65		.929	10.1	0.	1.
0.	.05		36.65		.929	10.1	0.	1.
0.	.075		36.65		.929	10.1	0.	1.
0.	.1		36.65		.929	10.1	0.	1.
0.	.125		36.65		.929	10.1	0.	1.
0.	.15		36.65		.929	10.1	0.	1.
0.	.175		36.65		.929	10.1	0.	1.
0.	.2		36.65		.929	10.1	0.	1.
0.	.225		36.65		.929	10.1	0.	1.
0.	.25		36.65		.929	10.1	0.	1.
0.	.275		36.65		.929	10.1	0.	1.
0.	.3		36.65		.929	10.1	0.	1.
0.	.325		36.65		.929	10.1	0.	1.
0.	.35		36.65		.929	10.1	0.	1.
0.	.375		36.65		.929	10.1	0.	1.
0.	.4		36.65		.929	10.1	0.	1.
0.	.425		36.65		.929	10.1	0.	1.
0.	.45		36.65		.929	10.1	0.	1.
0.	.475		36.65		.929	10.1	0.	1.
0.	.5		36.65		.929	10.1	0.	1.
0.	.525		36.65		.929	10.1	0.	1.
0.	.55		36.65		.929	10.1	0.	1.
0.	.575		36.65		.929	10.1	0.	1.
0.	.6		36.65		.929	10.1	0.	1.
0.	.625		36.65		.929	10.1	0.	1.
0.	.65		36.65		.929	10.1	0.	1.
0.	.675		36.65		.929	10.1	0.	1.
0.	.7		36.65		.929	10.1	0.	1.
0.	.725		36.65		.929	10.1	0.	1.
0.	.75		36.65		.929	10.1	0.	1.
0.	.775		36.65		.929	10.1	0.	1.
0.	.8		36.65		.929	10.1	0.	1.
0.	.825		36.65		.929	10.1	0.	1.
0.	.85		36.65		.929	10.1	0.	1.
0.	.875		36.65		.929	10.1	0.	1.
0.	.9		36.65		.929	10.1	0.	1.
0.	.925		36.65		.929	10.1	0.	1.
0.	.95		36.65		.929	10.1	0.	1.
0.	.975		36.65		.929	10.1	0.	1.
0.	1.		36.65		.929	10.1	0.	1.
9.	1.		1.		1.	0.	0.	

APPENDIX

PROGRAM LISTING

The following is a listing of the Fortran IV program for Source Flow Characteristic

PROGRAM NOZ BOD (INPUT,OUTPUT,PUNCH,TAPE5=INPUT,TAPE6=OUTPUT,
1 TAPE7=PUNCH)

COMMON/COWL/ICOWL,MM,XM(9),YM(9),PMM(9),WM(9),RHM(9),THM(9),QM(9),
1 RM(9),TM(9),GM(9),XMUM(9),EMM(9),ALPM(7,9),CPXM(9)

COMMON/IPP/IPP

COMMON/SHAPE/AA1(3,2),AA2(3,2),AA3(3,2),XXU(3),XXL(3),XINTU,XINTL

COMMON/L TM/XSHFT,YSHFT,XTHX,YLFT,XMOM

COMMON/XXJ/NXXJ1,XXJ1(6),AXX(6),BXX(6),XDR(6)

COMMON/XFINAL/XFINAL

COMMON/IEQ/IEQ,PIN,RHOINF,UINF,PINF

COMMON/VAR/RHO(200),

1 EM(200),XMU(200),CPX(200),W(200),R(200),GAM(200),XMASS(200),
2 XN(200),YN(200),QN(200),TN(200),PN(200),THN(200),RHON
3 (200),EMN(200),XMUN(200),CPXN(200),WN(200),RN(200),GAMN(200),
4 XMASN(200),ALPN(10,200),SI(10),HI(10),
5 ,ALPDUM(10),ERR(20),TEMP(20)

COMMON /SP/ NSP

COMMON/F VAR/

1 RHOF(200),CPXF(200),EMF(200),XMUF(200),WF(200),RF(200),GAMF(200),
2 XMASF(200),HF(200),SF(200),ALPD(10),
3 THETA(20)

COMMON/X/X(200),Y(200),P(200),Q(200),T(200),TH(200),ALP(10,200)

COMMON/I/ IOPUT

COMMON/A/ TIN,CPIN,RO

COMMON/B/ WTMOLE

COMMON/D/ GAMINF,EMINF,RINF,WINF

COMMON/F/A9,B9,IBOD,XWF,NBOD,YEND

COMMON/ETX/XJ,XJ1,NPTS,10,IREFL,ICHEM,IPUNCH,IDESGN,IR,NXX,XBP,
1 YBP,THBP,RAD,XBOD,YBOD,THBOD,RADB,XEND,THEND,RTH,YEXIT,THST,TEST,
1 IREFL,Y0,RADB2,RRAD(20),NSTAR,YNOZ,EIN,PEN,H16,H17

COMMON/XF/XF(200),YF(200),PF(200),QF(200),TF(200),THF(200),ALPF(110,200)

COMMON/XCOWL/XCOWL

COMMON/CMC1/EMC1,TC1,QC1

COMMON/I O V E R/ 1 O V E R

COMMON/XTJ1/XTJ1

COMMON/FENCE/IFENCE,AFENCE,BFENCE,XFENCE

DIMENSION WTMOLE(10)

DIMENSION ERAD(20)

DIMENSION TYPE2(2)

DIMENSION TYPE3(2)

DIMENSION TYPE9(2),PHIPR(2)

DATA PHIPR/3H ,3PHI/

DATA TYPE9/3HCPX,3PHI/

DATA TYPE3/3H W ,3HGAM/

DATA TYPE2 /10H NOZZLE ,10HCENTERBODY/

DATA XXP/1.E+06/

DATA ISHOC/-10000/

WRITE(6,400)

400 FORMAT(1H1)

J=0 TWO DIMENSIONAL

J=1 AXISYMMETRIC

SPECIES 1 IS H

SPECIES 2 IS O

SPECIES 3 IS H2O

SPECIES 4 IS H2

SPECIES 5 IS O2

SPECIES 6 IS OH

SPECIES 7 IS N2

SPECIES 8 IS CO2

C SPECIES 9 IS CO
 C SPECIES 10 IS C3H8
 IPTP=0
 NXXJ=2
 IFLIP=0
 IHALT=0
 ICMLT=0
 NSTAR=0
 IOPUT=32
 IEXIT=0
 IAA=1
 CALL INDATA
 XCOWLH=XCOWL
 IEQ5=IEQ+1
 YNOZ=YBP
 PEN= PIN
 XJ1SV=XJ1
 PF INF=PINF *144.7 PIN
 IFENC1=0
 7211 IPP=0
 LSTT=0
 WRITE(6,400)
 IF(IFENC1.EQ.1) WRITE(6,3100)
 3100 FORMAT(30X*FENCE INITIAL PROFILE*)
 IF(IFENC1.EQ.1) GO TO 3101
 IF(IPTP.EQ.0) WRITE(6,9191) XOR(1)
 9191 FORMAT(20X*INITIAL PROFILE*)
 1* - ORIGIN OF SYSTEM =*E13.5)
 IF(IFLIP.EQ.0.AND.IPTP.EQ.1.AND.XF(1).NE.XCOWLH) WRITE(6,9192)
 1 XOR(NXXJ-1)
 9192 FORMAT(16X*CHANGE OF ORIGIN PROFILE*)
 1* - ORIGIN OF SYSTEM =*E13.5)
 IF(IFLIP.EQ.0.AND.IPTP.EQ.1.AND.XF(1).EQ.XCOWLH) WRITE(6,3132)
 1 XOR(NXXJ-1)
 3132 FORMAT(8X*PROFILE FOR UNDER EXPANDED SHOCK AT COWL*)
 1* - ORIGIN OF SYSTEM =*E13.5)
 IF(IFLIP.EQ.1) WRITE(6,600) XOR(NXXJ-1)
 600 FORMAT(8X*PROFILE FOR OVER EXPANDED SHOCK AT COWL*)
 1* - ORIGIN OF SYSTEM =*E13.5)
 IF(IFLIP.EQ.2) WRITE(6,621) XOR(NXXJ-1)
 621 FORMAT(6X*PROFILE WHEN SHOCK REFLECTS OFF LOWER WALL*)
 1* - ORIGIN OF SYSTEM =*E13.5)
 3101 CONTINUE
 IEQ1=IEQ+1
 WRITE(6,6896) PHIPR(IEQ1)
 6896 FORMAT(1X,*X*,11X,*Y*,11X,*Q*,11X,*T*,11X,*P*,10X,*TH*10XA3)
 IF(ICHEM.EQ.0.AND.IEQ.EQ.0) WRITE(6,7701)
 7701 FORMAT(13X*ALP(1)=H*4X*ALP(2)=0*3X*ALP(3)=H20*2X*ALP(4)=H2*
 13X*ALP(5)=02*3X*ALP(6)=0H*3X*ALP(7)=N2*)
 KSIDE=0
 INDI3=0
 3160 CONTINUE
 FX2=0.
 XL Y2=0.
 XMOM2=0.
 XMAS22=0.
 DO 6897 I=1,NPTS
 YFPR1=YFPR
 THFPR1=THFPR

```

YFPR=YF(1)
THFPR=THF(1)
IF (IFL IP.EQ.1) YFPR=-YF(1)
IF (IFL IP.EQ.1) THFPR=-THF(1)
IF (XJ1SV.EQ.0.) GO TO 3102
IF (IPTP.EQ.0) GO TO 3103
IF (XF(I).EQ.XCOWLH) GO TO 3103
IF (IFENC1.EQ.1) GO TO 3103
GO TO 3102
3103 DO 3111 J=1,NSP
3111 ALPDUM(J)=ALPF(J,I)
CALL ALL(CPXF(I),WF(I),RHOE(I),RF(I),GAMF(I),EMF(I),XMUF(I),
1 QF(I),TF(I),PF(I),ALPDUM)
IF (I.EQ.1) GO TO 3102
JQ=I-1
DY13=YFPR-YFPR1
DX13=XF(I)-XF(JQ)
THS13=1.5707963
IF (DX13.GT.1.E-10) THS13=ATAN(DY13/DX13)
Z1=A XX(NXXJ-1)*(XF(JQ)-XBP)+BX X(NX XJ-1)
Z2=A XX(NXXJ-1)*(XF(I)-XBP)+BX X(NX XJ-1)
XBAR13=(XF(I)+XF(JQ))/2.-XSHFT
YBAR13=(YF(I)+YF(JQ))/2.-YSHFT
E1=GAMF(JQ)*PF(JQ)*EMF(JQ)*EMF(JQ)*SIN(THS13-THFPR1)/SIN(THS13)
E2=GAMF(I)*PF(I)*EMF(I)*EMF(I)*EMF(I)*SIN(THS13-THFPR1)/SIN(THS13)
F1=(E1*COS(THFPR1)+(PF(JQ)-PIN))
F2=(E2*COS(THFPR1)+(PF(I)-PIN))
E11=RHOE(JQ)*QF(JQ)*SIN(THS13-THFPR1)/SIN(THS13)
E22=RHOE(I)*QF(I)*SIN(THS13-THFPR1)/SIN(THS13)
ZBAR=(Z1+Z2)/2.
XMS13=(E11+E22)*DY13/2.*ZBAR
XMAS22=XMAS22+XMS13
FFX2=(F1+F2)/2.*DY13*PFINF*ZBAR
COTTHS=COS(THS13)/SIN(THS13)
XL LY1=(E1*SIN(THFPR1)+(PF(JQ)-PIN)*COTTHS)
XL LY2=(E2*SIN(THFPR1)+(PF(I)-PIN)*COTTHS)
XXLY2=(XL LY1+XL LY2)/2.*DY13*PFINF*ZBAR
XMOM2=XMOM2+FFX2*YBAR13-XXLY2*XBAR13
FX2=FX2+FFX2
XL Y2=XL Y2+XXLY2
IF (I.LT.NPTS) GO TO 3102
IF (IPTP.NE.0) GO TO 3105
FX1=FX2
XL Y1=XL Y2
XMOM1=XMOM2
XMAS12=XMAS22
GO TO 3102
3105 IF (IFENC1.EQ.1) GO TO 3106
IF (XF(I).NE.XCOWLH) GO TO 3102
3106 XTHXMS=FX2-FX1-XTHX
XMOMMS=XMOM2-XMOM1-XMOM
RATM=XMAS22/XMAS12
EMS=RATM-1.
IF (ABS(EMS).LT.1.E-03) GO TO 3161
IND13=IND13+1
IF (IND13.GT.1) GO TO 3161
CALL XMASSS(RATM,NPTS)
GO TO 3160
3161 CONTINUE
KSIDE=1

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3102 CONTINUE
6897 CONTINUE
DO 3163 I=1,NPTS
C=PF(I)/PIN
YFPR=YF(I)
THFPR=THF(I)
IF(IFLIP.EQ.1) YFPR=-YF(I)
IF(IFLIP.EQ.1) THFPR=-THF(I)
IF(IEQ.EQ.1) GO TO 9806
WRITE(6,16) I,XF(I),YFPR,QF(I),TF(I),C,THFPR
WRITE(6,1602) ALPF(J,I),J=1,NSP
GO TO 3163
9806 WRITE(6,16) I,XF(I),YFPR,QF(I),TF(I),C,THFPR,RF(I)
3163 CONTINUE
1800 FORMAT(* UNDERSURFACE AND COWL THRUST =#E13.5,7X*LIFT =#E13.5,7X*M
10MENT =#E13.5)
IPTP=1
XJ1SV=XJ1
WRITE(6,3130)
3130 FORMAT(/)
IF(KSIDE.EQ.0) GO TO 3104
WRITE(6,1800) XTHX,YLFT,XMOM
WRITE(6,3107) XTHXMS,XMOMMS
3107 FORMAT(5X* SIDEWALL THRUST =#E12.4,5X*SIDEWALL MOMENT =#E12.4//)
3104 CONTINUE
N=2
LMAX=1
KMAX=2*(N-1)-1
IF(IVOVER.NE.2) GO TO 7423
N=3
IPP=1
LMAX=2
KMAX=2
7423 NN1=N-1
DO 7424 I=1,NN1
II=NN1-I+1
X(I)=XF(II)
Y(I)=YF(II)
Q(I)=QF(II)
T(I)=TF(II)
P(I)=PF(II)
TH(I)=THF(II)
W(I)=WF(II)
R(I)=RF(II)
DO 505 J=1,NSP
505 ALP(J,I)=ALPF(J,II)
DO 1500 J=1,NSP
1500 ALPDUM(J)=ALP(J,I)
CALL ALL(CPX(I),W(I),RHO(I),R(I),GAM(I),EM(I),XMU(I),Q(I),T(I),
1P(I),ALPDUM)
7424 CONTINUE
500 CONTINUE
IF(KMAX.GE.191) GO TO 9123
6060 IPP=IPP+1
6883 WRITE(6,7633) IPP
7633 FORMAT(5X,*LINE NO.=*,I4)
IF(IVOVER.EQ.2.AND.KMAX.GE.10) GO TO 670
JJ=1+KMAX/10
JJ1=KMAX-1
IF(IVO.EQ.1) JJ=1

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      WRITE(6,6885)TYPE3(IEQ5),TYPE9(IEQ5)
16 FORMAT(3X,I4,3X,10E12.4)
6885 FORMAT(5X,*PT. *,8X,*X*,11X,*Y*,11X,*P*,10X,*TH*,11X,*Q*,11X,*T*,
110X,*EM*,10X,A3 , 9X,A3)
      DO 7637 I=1, JJ1, JJ
      C=P(I)/PIN
      YFPR=Y (I)
      THFPR=TH (I)
      DUPR=W(I)
      IF(IEQ5.EQ.2) DUPR=GAM(I)
      CPR=CPX(I)
      IF(IEQ.EQ.1) CPR=R(I)
      IF(IFLIP.EQ.1) YFPR=-Y (I)
      IF(IFLIP.EQ.1) THFPR=-TH (I)
      WRITE(6,7632) I,X(I),YFPR,C ,THFPR,Q(I),T(I),EM(I),DUPR,CPR
7632 FORMAT(3X,I4,3X,10E12.4)
7637 CONTINUE
1602 FORMAT(10X,10E12.4)
      IF(IPP.EQ.1) GO TO 7759
      I=KMAX
      C=P(I)/PIN
      YFPR=Y (I)
      THFPR=TH (I)
      DUPR=W(I)
      IF(IEQ5.EQ.2) DUPR=GAM(I)
      CPR=CPX(I)
      IF(IEQ.EQ.1) CPR=R(I)
      IF(IFLIP.EQ.1) YFPR=-Y (I)
      IF(IFLIP.EQ.1) THFPR=-TH (I)
      WRITE(6,7632) I,X(I),YFPR,C ,THFPR,Q(I),T(I),EM(I),DUPR,CPR
      GO TO 7759
670 JJ=1+KMAX/10
      JJ2=1
      ISH=ISH0C
      JJ1=ISH-1
      WRITE(6,6885)TYPE3(IEQ5)
672 DO 671 I=JJ2,JJ1,JJ
      C=P(I)/PIN
      YFPR=Y (I)
      THFPR=TH (I)
      DUPR=W(I)
      IF(IEQ5.EQ.2) DUPR=GAM(I)
      CPR=CPX(I)
      IF(IEQ.EQ.1) CPR=R(I)
      IF(IFLIP.EQ.1) YFPR=-Y (I)
      IF(IFLIP.EQ.1) THFPR=-TH (I)
      WRITE(6,7632) I,X(I),YFPR,C ,THFPR,Q(I),T(I),EM(I),DUPR,CPR
671 CONTINUE
      I=JJ1+1
      C=P(I)/PIN
      YFPR=Y (I)
      THFPR=TH (I)
      DUPR=W(I)
      IF(IEQ5.EQ.2) DUPR=GAM(I)
      CPR=CPX(I)
      IF(IEQ.EQ.1) CPR=R(I)
      IF(IFLIP.EQ.1) YFPR=-Y (I)
      IF(IFLIP.EQ.1) THFPR=-TH (I)
      WRITE(6,7632) I,X(I),YFPR,C ,THFPR,Q(I),T(I),EM(I),DUPR,CPR
      IF(JJ1.EQ.KMAX-1) GO TO 7759

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JJ2=ISH+1
JJ1=KMAX-1
GO TO 672
7759 BETPR=GET
WRITE(6,1800) XTHX,YLFT,XMOM
IF(IFLIP.EQ.1) BETPR=-BET
IF(IOVER.EQ.2) WRITE(6,653) BETPR,EMC1
653 FORMAT(5X*SHOCK ANGLE =#E12.4,5X*EXTERNAL MACH NO. =#E12.4)
WRITE(6,1603)
1603 FORMAT(///)
6884 ICMP=ICMPLT+1
IF(IOVER.NE.2) GO TO 2658
ISHOC=ISHOC+1
IF(NSTAR.EQ.1) ISHOC=ISHOC-2
2658 CONTINUE
IF(IHALT.EQ.1) STOP
IF(IFLIP.EQ.2.AND.N.GT.NPTS) STOP
GO TO (4300,4301,4302,4303),ICMP
4301 IF(ICOWL.EQ.0) STOP
ICMPLT=2
CALL COWL(-1.)
IPM=1
4302 IPM=IPM+1
IF(IPM.GT.MM-3) GO TO 4303
LMAX=KMAX+1
X N(1)=X M(IPM)
Y N(1)=Y M(IPM)
P N(1)=P MM(IPM)
W N(1)=W M(IPM)
Q N(1)=Q M(IPM)
R N(1)=R M(IPM)
T N(1)=T M(IPM)
TH N(1)=TH M(IPM)
EM N(1)=EM M(IPM)
RHON(1)=RH M(IPM)
GAMN(1)=G M(IPM)
XMUN(1)=XMUM(IPM)
CPXN(1)=0.
IF(IEQ.EQ.0) CPXN(1)=CPXM(IPM)
DO 4304 J=1,NSP
ALPN(J,1)=0.
4304 IF(IEQ.EQ.0) ALPN(J,1)=ALPM(J,IPM)
GO TO 8060
4303 ICMPLT=3
STOP
4300 IF(X(1).EQ.XCOWLH.AND.IPP.EQ.NPTS.AND.IOVER.NE.2) GO TO 4301
IF(N.GT.NPTS) GO TO 8104
LMAX=LMAX+2
L=1
K=1
DO 510 J=1,NSP
510 ALPN(J,L)=ALPF(J,N)
XN(L)=XF(N)
YN(L)=YF(N)
QN(L)=QF(N)
PN(L)=PF(N)
TN(L)=TF(N)
THN(L)=THF(N)
WN(L)=WF(N)
RN(L)=RF(N)

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DO 1501 J=1,NSP
1501 ALPDUM(J)=ALPN(J,1)
    CALL ALL (CPXN(1),WN(1),RHON(1),RN(1),GAMN(1),EMN(1),XMUN(1),QN(1)
    1,TN(1),PN(1),ALPDUM)
    IF ENCL=1
    IF(IFENCE.EQ.1.AND.XN(L).EQ.XCOWLH.AND.N.EQ.NPTS) GO TO 2601
    IF ENCL=0
    GO TO 8060
8104 ASL=TAN(TH(1))
    ACH=TAN(TH(2)+XMU(2))
    XN(1)=(Y(1)-Y(2)+X(2)*ACH-X(1)*ASL)/(ACH-ASL)
    DELTH=XN(1)-X(1)
    IF((DELTH/TEST).GT.1.) GO TO 9061
    ICK=1
3514 YCH=Y(2)+ACH*(XN(1)-X(2))
    CALL BODU(XN(1),YN(1),THN(1))
    IF (I OVER.NE.2) GO TO 694
    YN(1)=-YN(1)
    THN(1)=-THN(1)
694 CONTINUE
    DELTH=ABS(THN(1)-TH(1))
    IF(DELTH.GT.,02) GO TO 9061
    ER=(YCH-YN(1))
    IF (ABS(ER).LT.1.E-04) GO TO 3510
    ICK=ICK+1
    IF(ICK.LT.15) GO TO 3511
    WRITE(6,3512)
3512 FORMAT(* TOO MANY ITERATIONS IN INITIAL BODU CALL FROM NOZBOD*)
    STOP
3511 IF(ICK.GT.2) GO TO 3513
    ER1=ER
    XSL1=XN(1)
    XN(1)=1.01*XN(1)
    GO TO 3514
3513 DUM=XSL1-ER1*(XN(1)-XSL1)/(ER-ER1)
    ER1=ER
    XSL1=XN(1)
    XN(1)=DUM
    GO TO 3514
3510 CONTINUE
    XSL=XN(1)
    YSL=YN(1)
    THSL=THN(1)
    IF((DELTH/TEST).LT.1.) GO TO 9060
    DELTH=XN(1)-X(1)
9061 LMAX=KMAX+1
    DO 9000 M1=2,KMAX
    L=KMAX-M1+2
    I=L+1
    X(I)=X(L)
    Y(I)=Y(L)
    Q(I)=Q(L)
    P(I)=P(L)
    T(I)=T(L)
    W(I)=W(L)
    R(I)=R(L)
    TH(I)=TH(L)
    EM(I)=EM(L)
    CPX(I)=CPX(L)
    RHO(I)=RHO(L)

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GAM(I)=GAM(L)
XMU(I)=XMU(L)
DO 9001 J=1,NSP
9001 ALP(J,I)=ALP(J,L)
9000 CONTINUE
ISHOC=ISHOC+1
KMAX=KMAX+1
RAT=.5
X(2)=X(1)+RAT*(X(3)-X(1))
Y(2)=Y(1)+RAT*(Y(3)-Y(1))
Q(2)=Q(1)+RAT*(Q(3)-Q(1))
T(2)=T(1)+RAT*(T(3)-T(1))
TH(2)=TH(1)+RAT*(TH(3)-TH(1))
R(2)=R(1)+RAT*(R(3)-R(1))
CALL PANDW(P(1),P(3),RAT,P(2),W(1),W(3),Q(1),Q(3),Q(2),W(2),IEQ,0)
DO 9003 J=1,NSP
ALP(J,2)=ALP(J,1)+RAT*(ALP(J,3)-ALP(J,1))
9003 ALPDUM(J)=ALP(J,2)
CALL ALL(CPX(2),W(2),RHO(2),R(2),GAM(2),EM(2),XMU(2),Q(2),T(2),
1P(2),ALPDUM)
GO TO 8104
9060 LMAX=KMAX
A=1.
B=0.
IF (ISHOC.EQ.1) BETN=BET
8000 CONTINUE
IF (B.EQ.0) THN(1)=THSL
IT=1
8030 EMSL=XM3(.5,.5,TH(1),THN(1))
EM1=XM1(A,B,TH(2),XMU(2),THN(1),XMUN(1))
IF (ISHOC.EQ.1) EM1=.5*(TAN(BET)+TAN(BETN))
XN(1)=(Y(1)-Y(2)+X(2)*EM1-X(1)*EMSL)/(EM1-EMSL)
ICK=1
3524 YCH=Y(2)+EM1*(XN(1)-X(2))
CALL BODU(XN(1),YN(1),THN(1))
IF (IOVER.NE.2) GO TO 698
YN(1)=-YN(1)
THN(1)=-THN(1)
698 CONTINUE
ER=(YCH-YN(1))
IF (ABS(ER).LT.1.E-04) GO TO 3520
ICK=ICK+1
IF (ICK.LT.15) GO TO 3521
WRITE(6,3522)
3522 FORMAT(* TOO MANY ITERATIONS IN FINAL BODU CALL FROM NOZBOD*)
STOP
3521 IF (ICK.GT.2) GO TO 3523
ER1=ER
XSL1=XN(1)
XN(1)=1.01*XN(1)
GO TO 3524
3523 DUM=XSL1-ER1*(XN(1)-XSL1)/(ER-ER1)
ER1=ER
XSL1=XN(1)
XN(1)=DUM
GO TO 3524
3520 CONTINUE
8020 A1=F1(A,B,XMU(2),GAM(2),P(2),XMUN(1),GAMN(1),PN(1))
XDUM2=X(2)-XOR(NXXJ-1)
XDUMN=XN(1)-XOR(NXXJ-1)

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A2=F2(A,B,1.,XJ,XJ1,XDUM2,Y(2),TH(2),XMU(2),XDUMN,YN(1),THN(1),XMU
1N(1))
DUM1=A2*(XN(1)-X(2))
IF(XJ1.GT.0.) DUM1=A2*ALOG(XDUMN/XDUM2)
DUM=(TH(2)-THN(1)-DUM1)/A1
PN(1)=P(2)*EXP(DUM)
IF(B.EQ.0.) GO TO 1801
L1=1
L2=1
IF(XN(L1).GT.XCOWL-1.E-04) GO TO 1801
IF(XN(L1).GT.XXJ1(NXJ)-1.E-04) GO TO 1801
Z1=A*XX(NXJ-1)*(X(L2)-XBP)+B*XX(NXJ-1)
Z2=A*XX(NXJ-1)*(XN(L1)-XBP)+B*XX(NXJ-1)
DA X=(Z1+Z2)/2.*ABS(YN(L1)-Y(L2))
DA Y=(Z1+Z2)/2.*(XN(L1)-X(L2))
PA V=(PN(L1)+P(L2))/2.
PA V=(PA V/P JN-1.)*P INF* 14 4.
DX TH X=PA V*DA X
DY LF T=-PA V*DAY
XMS=(XN(L1)+X(L2))/2. -XS HFT
YMS=(YN(L1)+Y(L2))/2. -YS HFT
DMOM=YMS*D TH X-XMS*D YLF T
XT HX=X TH X+DX TH X
YLFT=YLFT+DY LF T
XMOM=XMOM+DMOM
1801 CONTINUE
DO 8050 J=1,NSP
ALPN(J,1)=ALP(J,1)
8050 ALPDUM(J)=ALPN(J,1)
IF(IEQ.EQ.1) GO TO 3000
TERM2=RHO(1)*Q(1)*A
IF(B.GT.0.) TERM2=TERM2+B*RHO(1)*QN(1)
IF(B.EQ.0.) CP XN(1)=CP X(1)
QN(1)=(P(1)-PN(1))/TERM2+Q(1)
TN(1)=T(1)+(QN(1)+Q(1))*(PN(1)-P(1))*EIN/(CP X(1)+CP XN(1))/TERM2
CALL ALL(CPXN(1),WN(1),RHO(1),RN(1),GAMN(1),EMN(1),XMUN(1),
1QN(1),TN(1),PN(1),ALPDUM)
GO TO 3001
3000 CONTINUE
RHO(1)=RHO(1)*(PN(1)/P(1))*#*(1./GAM(1))
VVL=Q(1)*Q(1)+2.*GAM(1)/(GAM(1)-1.)*(P(1)/RHO(1)-PN(1)/RH
1ON(1))
QN(1)=SQRT(VVL)
WN(1)=W(1)+.5*(Q(1)*Q(1)-VVL)
RN(1)=R(1)
TN(1)=FT(PN(1),RN(1),WN(1))
GAMN(1)=FGAM(TN(1),PN(1),RN(1))
EMN(1)=QN(1)/SQRT(GAMN(1)*PN(1)/RHO(1))
XMUN(1)=ATAN(1./SQRT(EMN(1)*#2-1.))
3001 CONTINUE
IF(B.GT.0.) GO TO 8049
A=.5
B=.5
GO TO 8000
8049 IF(ISHOC.NE.1) GO TO 2600
CALL SHOCPT(ISHOC,3,BET,BETN,A,B)
BET=THN(2)-(BETN-THN(1))
IGC=1
2625 CALL SHOCK(BET,QN(2),THN(2),GAMN(2),EMN(2),RHO(2),PN(2),WN(2),
1RN(2),QN(1),TH2,GAMN(1),EMN(1),RHO(1),PN(1),WN(1),RN(1),TN(1))

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1 XMUN(1), -1.)
ER4=THN(1)-TH2
IF (ABS(ER4).LT.1.E-04) GO TO 2601
IGG=IGG+1
IF (IGG.GT.15) GO TO 2627
IF (IGG.GT.2) GO TO 2628
ER1=ER4
BETP=BET
BET=BET+.02
GO TO 2625
2627 WRITE(6,2629)
2629 FORMAT(* ERROR IN BETA LOOP IN MAIN*)
STOP
2628 DUMM=BETP-ER1*(BET-BETP)/(ER4-ER1)
ER1=ER4
BETP=BET
BET=DUMM
GO TO 2625
2600 CONTINUE
IF (IFLIP.EQ.1.AND,XN(1).GT.XFINAL) IHALT=1
IF (XN(1).LE.XCOWL-1.E-04.AND,XN(1).LE.XXJ1(NXXJ)-1.E-04) GOTO 8060
XNN=XCOWL
IF (XN(1).GT.XXJ1(NXXJ)-1.E-04) XNN=XXJ1(NXXJ)
RAT=(XNN-X(1))/(XN(1)-X(1))
XN(1)=XNN
CALL BODU(XN(1),YN(1),THN(1))
P_N(1)=P_(1)+RAT*(P_N(1)-P_(1))
L1=1
L2=1
Z1=AXX(NXXJ-1)*(X(L2)-XBP)+BXX(NXXJ-1)
Z2=AXX(NXXJ-1)*(XN(L1)-XBP)+BXX(NXXJ-1)
DAX=(Z1+Z2)/2.*ABS(YN(L1)-Y(L2))
DAY=(Z1+Z2)/2.*(XN(L1)-X(L2))
PAV=(P_N(L1)+P(L2))/2.
PAV=(PAV/PIN-1.)*PINF*14.4.
DXTHX=PAV*DAx
DYLF=PAV*DAY
XMS=(XN(L1)+X(L2))/2.-XSHFT
YMS=(YN(L1)+Y(L2))/2.-YSHFT
DMOM=YMS*DXTX-XMS*DYLFT
XTX=XTHX+DXTHX
YLF=YLF+DYLFT
XMOM=XMOM+DMOM
Q_N(1)=Q_(1)+RAT*(Q_N(1)-Q_(1))
T_N(1)=T_(1)+RAT*(T_N(1)-T_(1))
RN(1)=R(1)+RAT*(RN(1)-R(1))
WNT=WN(1)+QN(1)*QN(1)/2.
WT=W(1)+Q(1)*Q(1)/2.
WNT1=WT+RAT*(WNT-WT)
WN(1)=W(1)+RAT*(WN(1)-W(1))
IF (IEQ.EQ.1) WN(1)=WNT1-QN(1)*QN(1)/2.
DO 3519 J=1,NSP
ALPN(J,1)=ALP(J,1)
3519 ALPDUM(J)=ALP(J,1)
CALL ALL(CPXM(1),WN(1),RHON(1),RN(1),GAMN(1),EMN(1),XMUN(1),
1 QN(1),TN(1),PN(1),ALPDUM)
2601 CONTINUE
ICMPLT=1
IF (XJ1.EQ.0..AND,IOVER.EQ.0) GO TO 8060
IX=1

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IF (IFLIP.EQ.1) IX=2
2655 IAA=IAA+1
XF(IAA)=XN(IX)
YF(IAA)=YN(IX)
PF(IAA)=PN(IX)
QF(IAA)=QN(IX)
RF(IAA)=RN(IX)
WF(IAA)=WN(IX)
TF(IAA)=TN(IX)
THF(IAA)=THN(IX)
XMUF(IAA)=XMUN(IX)
GAMF(IAA)=GAMN(IX)
EMF(IAA)=EMN(IX)
RHOF(IAA)=RHON(IX)
DO 3470 J=1,NSP
3470 ALPF(J,IAA)=ALPN(J,IX)
IF (IX.EQ.1) GO TO 2656
IX=1
GO TO 2655
2656 IF (IFLIP.EQ.1) IAA=IAA-1
ICMP LT=0
NSTAR=0
IF (XN(1)+.0001.GE.XTJ1) XJ1=0.
IF (IFLIP.NE.1) NXXJ=NXXJ+1
IF (IFENC1.EQ.1) IFENCE=0
IF (NXXJ.GT.NXXJ1) NXXJ=NXXJ1+1
IF (XN(1).EQ.XCOWL) XCOWL=XFINAL
IF (IFLIP.GT.0) GO TO 2602
IF (ICOWL.EQ.0) GO TO 7593
RP=PMM(MM)/PF(IAA)*PIN
IF (RP.GT.1.) GO TO 5989
7593 NPTS=IAA
IOVER=0
IAA=1
GO TO 7211
5989 CONTINUE
EMEXT=EM INF*QM(MM)/SQR(T(MM))
CALL COWLO(IAA,THM(MM),EMEXT,BET,PMM(MM))
XINTU=XINTL
DO 691 I13=1,3
XXU(113)=XXL(I13)
AA1(I13,1)=AA1(I13,2)
AA2(I13,1)=AA2(I13,2)
691 AA3(I13,1)=AA3(I13,2)
2602 CONTINUE
NPTS=IAA+1
IFLIP=IFLIP+1
IF (IFLIP.GT.1) XXP=XFINAL
IAA=1
LSTT=0
IOVER=2
CALL INDATA
BET=-BET
ISHOC=1
GO TO 7211
8060 CONTINUE
LM=LMAX-1
IF (XJ1.GT.0..AND.IAA.GT.1) LM=1000
IF (IOVER.EQ.2..AND.LSTT.EQ.1) LM=1000
LST=0

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L=1
M=0
IDPT=0
XXP=XFINAL
IF(NSTAR.EQ.1) M=2
IF(ICMPLT.EQ.2) M=1
5520 L=L+1
IF(L.GT.LM) GO TO 6520
K=L-1
678 M=M+1
A=1.
B=0.
250 CONTINUE
IF(L.EQ.ISHOC+1) CALL SHOCPT(ISHOC,M,BET,BETN,A,B)
IF(L.NE.ISHOC+1.OR.B.EQ.0..OR.IFLIP.NE.1) GO TO 2603
IPL=3
2684 POLYC=-AA3(IPL,1)-YN(L)+TAN(BETN)*(XN(L)-XINTU)
POLYB=-AA2(IPL,1)-TAN(BETN)
POLYA=-AA1(IPL,1)
IF(POLYA.NE.0.)
1XXP=(-POLYB-SQRT(POLYB*POLYB-4.*POLYA*POLYC))/(2.*POLYA)
IF(POLYA.EQ.0.) XXP=POLYC/POLYB
XXP=XXP+XINTU
IF(XXP.GE.XXU(IPL)) GO TO 2603
IPL=IPL-1
GO TO 2684
2603 CONTINUE
IF(L.EQ.ISHOC+1) GO TO 3003
EM1=XM1(A,B,TH(M),XMU(M),THN(L),XMUN(L))
EM9=EM1
IF(L.EQ.ISHOC) EM1=TAN(BET)
IF(L.EQ.ISHOC.AND.M.GT.1)EM1=TAN(BET+THN(L-1)+XMUN(L-1)-TH(M-1)
1-XMU(M-1))
EM2=XM2(A,B,THN(K),XMUN(K),THN(L),XMUN(L))
XN(L)=(YN(K)-Y(M)+EM1*X(M)-EM2*XN(K))/EM1-EM2
YN(L)=Y(M)+EM1*(XN(L)-X(M))
IF(B.GT.0.) GO TO 681
IDROP=0
BETT=BET
IF(M.GT.1.AND.IOVER.EQ.2)BETT=BET+THN(L-1)+XMUN(L-1)-TH(M-1)-XMU(M
1-1)
IF(L.EQ.ISHOC-1) CALL DRTEST(XN(L),YN(L),EM1,BETT,IDROP,+1,M)
IF(L.EQ.ISHOC+2) CALL DRTEST(XN(L),YN(L),EM1,BETN,IDROP,-1,M)
IF(IDROP.EQ.0) GO TO 681
LMAX=LMAX-1
LM=LM-1
IF(L.LT.ISHOC) ISHOC=ISHOC-1
GO TO 678
681 CONTINUE
IF(L.NE.ISHOC) GO TO 601
YSHOC=Y(M)
XSHOC=X(M)
IF(L.GT.2) GO TO 602
YDUM=YN(L)-EM9*(XN(L)-X(M))
XDUM=X(M)
RATE=(YDUM-Y(M))/(YN(1)-Y(M))
Y(M)=YDUM
X(M)=XDUM
QHD=Q(M)
Q(M)=Q(M)+RATE*(Q(N-1)-Q(M))

```

```

T (M)=T (M)+RAT*(T N( 1)-T (M))
R (M)=R (M)+RAT*(R N( 1)-R (M))
CALL PANDW(P(M),PN(1),RAT,P(M),W(M),WN(1),GHO,QN(1),Q(M),W(M),IEQ
1,0)
TH (M)=TH (M)+RAT*(TH N( 1)-TH (M))
XMU(M)=XMU(M)+RAT*(XMUN( 1)-XMU(M))
GAM(M)=GAM(M)+RAT*(GAMN( 1)-GAM(M))
DO 644 J=1,NSP
644 ALP(J,M)=ALP(J,M)+RAT*(ALPN(J, 1)-ALP(J,M))
GO TO 601
602 CONTINUE
EM8=XM2(.5,.5,TH(M-1),XMU(M-1),TH(M),XMU(M))
YDUM=(EM9*Y(M)-EM8*YN(L)+EM8*EM9*(XN(L)-X(M)))/(EM9-EM8)
XDUM=XN(L)-(YN(L)-YDUM)/EM9
RAT=(YDUM-Y(M))/(Y(M-1)-Y(M))
Y(M)=YDUM
X(M)=XDUM
QHO=Q(M)
Q (M)=Q (M)+RAT*(Q (M-1)-Q (M))
T (M)=T (M)+RAT*(T (M-1)-T (M))
R (M)=R (M)+RAT*(R (M-1)-R (M))
CALL PANDW(P(M),P(M-1),RAT,P(M),W(M),W(M-1),QHO,Q(M-1),Q(M),W(M)
1,IEQ,0)
TH (M)=TH (M)+RAT*(TH (M-1)-TH (M))
XMU(M)=XMU(M)+RAT*(XMU(M-1)-XMU(M))
GAM(M)=GAM(M)+RAT*(GAM(M-1)-GAM(M))
DO 604 J=1,NSP
604 ALP(J,M)=ALP(J,M)+RAT*(ALP(J,M-1)-ALP(J,M))
601 CONTINUE
A1=F1(A,B,XMU(M),GAM(M),P(M),XMUN(L),GAMN(L),PN(L))
B1=F1(A,B,XMUN(K),GAMN(K),PN(K),XMUN(L),GAMN(L),PN(L))
XDUMK=XN(K)-XOR(NXXJ-1)
XDUMM=X(M)-XOR(NXXJ-1)
XDUML=XN(L)-XOR(NXJ-1)
A2=F2(A,B,1.,XJ,XJ1,XDUMM,Y(M),TH(M),XMU(M),XDUML,YN(L),THN(L),XMU
1N(L))
B2=F2(A,B,-1.,XJ,XJ1,XDUMK,YN(K),THN(K),XMUN(K),XDUML,YN(L),THN(L)
1,XMUN(L))
DUM1=-(A2+B2)*XN(L)+A2*X(M)+B2*XN(K)
IF(XJ1.GT.0.)DUM1=-(A2*ALOG(XDUML/XDUMM)+B2*ALOG(XDUML/XDUMK))
DUM=(A1*ALOG(P(M))+B1*ALOG(PN(K))+TH(M)-THN(K)+DUM1)/(A1+B1)
PN(L)=EXP(DUM)
DUM=ALOG(P(M)/PN(L))*A1
DUM2=XN(L)-X(M)
IF(XJ1.NE.0.) DUM2=ALOG(XDUML/XDUMM)
THN(L)=DUM+TH(M)-A2*DUM2
253 EM3A=XM3(.5,.5,TH(M),THN(L))
EM3B=XM3(.5,.5,THN(K),THN(L))
EM3=.5*(EM3A+EM3B)
TESTX=ABS(XN(K)-X(M))
TESTY=ABS(YN(K)-Y(M))
IF(TESTX.GE.1.E-10)
1 SLOPE=(YN(K)-Y(M))/(XN(K)-X(M))
IF(TESTX.LT.1.E-10) SLOPE=1.E10
XD=(YN(L)-Y(M)+SLOPE*X(M)-EM3*XN(L))/(SLOPE-EM3)
IF(NSTAR.EQ.0) GO TO 6881
XX=ABS(1.-X(M)/XN(K))
IF(XX.LT..001) XD=(XN(K)+X(M))/2.
6881 YD=YN(L)+EM3*(XD-XN(L))
IF(TESTX.LE.TESTY) GO TO 2250

```

KIP=0
 2230 RATD=(XD-X(M))/(XN(K)-X(M))
 THD=TH(M)+RATD*(THN(K)-TH(M))
 EM3=XM3(.5,.5,THD,THN(L))
 XDT=XD
 XD=(YN(L)-Y(M)+SLOPE*X(M)-EM3*XN(L))/(SLOPE-EM3)
 YD=YN(L)+EM3*(XD-XN(L))
 IF(ABS((XDT-XD)/TESTX).LT..001) GO TO 2231
 KIP=KIP+1
 IF(KIP.GT.20) CALL ERROR(2230)
 GO TO 2230
 2231 RATD=(XD-X(M))/(XN(K)-X(M))
 GO TO 2235
 2250 CONTINUE
 KIP=0
 230 RATD=(YD-Y(M))/(YN(K)-Y(M))
 THD=TH(M)+RATD*(THN(K)-TH(M))
 EM3=XM3(.5,.5,THD,THN(L))
 YDT=YD
 XD=(YN(L)-Y(M)+SLOPE*X(M)-EM3*XN(L))/(SLOPE-EM3)
 YD=YN(L)+EM3*(XD-XN(L))
 IF(ABS((YDT-YD)/(YN(K)-Y(M))).LT..001) GO TO 231
 KIP=KIP+1
 IF(KIP.GT.20) CALL ERROR(230)
 GO TO 230
 231 RATD=(YD-Y(M))/(YN(K)-Y(M))
 2235 CONTINUE
 QD=Q(M)+RATD*(QN(K)-Q(M))
 TD=T(M)+RATD*(TN(K)-T(M))
 THD=TH(M)+RATD*(THN(K)-TH(M))
 PD=P(M)+RATD*(PN(K)-P(M))
 RD=R(M)+RATD*(RN(K)-R(M))
 WM T=W(M)+Q(M)*Q(M)/2.
 WK T=WN(K)+QN(K)*QN(K)/2.
 WD T=WM T+RATD*(WK T-WM T)
 WD=W(M)+RATD*(WN(K)-W(M))
 IF(I.EQ.EQ.1) WD=WD T-QD*QD/2.
 DO 235 J=1,NSP
 235 ALPD(J)=ALP(J,M)+RATD*(ALPN(J,K)-ALP(J,M))
 CALL ALL(CPXD,WD,RHOD,RD,GAMD,EMD,XMUD,QQ,TD,PD,ALPD)
 DO 1502 J=1,NSP
 ALPN(J,L)=ALPD(J)
 1502 ALPDUM(J)=ALPN(J,L)
 IF(I.EQ.EQ.1) GO TO 3002
 TERM2=RHOD*QD
 IF(B.GT.0.) TERM2=(TERM2+RHON(L)*QN(L))/2.
 IF(B.EQ.0.) CPXN(L)=CPXD
 QN(L)=(PD-PN(L))/TERM2+QD
 TN(L)=TD+(QN(L)+QD)*(PN(L)-PD)*EIN/(CPXD+CPXN(L))/TERM2
 CALL ALL(CPXN(L),WN(L),RHON(L),RN(L),GAMN(L),EMN(L),XMUN(L),QN(L),
 1,TN(L),PN(L),ALPDUM)
 GO TO 3003
 3002 CONTINUE
 RHON(L)=RHOD*(PN(L)/PD)*(1./GAMD)
 VVL=QD*QD+2.*GAMD/(GAMD-1.)*(PD/RHOD-PN(L)/RH
 1.ON(L))
 QN(L)=SQRT(VVL)
 WN(L)=WD+.5*(QD*QD-VVL)
 RN(L)=RD
 TN(L)=FT(PN(L),RN(L),WN(L))

GAMN(L)=FGAM(TN(L),PN(L),RN(L))
EMN(L)=GN(L)/SQRT(GAMN(L)*PN(L)/RHON(L))

XMUN(L)=ATAN(1./SQRT(EMN(L)*#2-1.))

3003 CONTINUE

IF (IDPT.EQ.0) GO TO 8400
IF (B.GT.0.) GO TO 8401

A=.5

B=.5

GO TO 253

8400 CONTINUE

IF (B.GT.0.) GO TO 7520

IF (L.NE.ISHOC) GO TO 606

IF (L.GT.2) GO TO 650

RAT=(YN(1)-YSHOC)/(YN(1)-Y(M))

Y(M)=YSHOC

X(M)=XSHOC

QHO=Q(M)

Q(M)=Q(M)+RAT*(Q(N(1))-Q(M))

T(M)=T(M)+RAT*(T(N(1))-T(M))

R(M)=R(M)+RAT*(R(N(1))-R(M))

CALL PANDW(P(M),PN(1),RAT,P(M),W(M),WN(1),QHO,QN(1),Q(M),W(M),IEQ1,0)

TH(M)=TH(M)+RAT*(TH(N(1))-TH(M))

XMU(M)=XMU(M)+RAT*(XMUN(1)-XMU(M))

GAM(M)=GAM(M)+RAT*(GAMN(1)-GAM(M))

DO 655 J=1,NSP

655 ALP(J,M)=ALP(J,M)+RAT*(ALPN(J,1)-ALP(J,M))

GO TO 606

650 CONTINUE

RAT=(Y(M-1)-YSHOC)/(Y(M-1)-Y(M))

Y(M)=YSHOC

X(M)=XSHOC

QHO=Q(M)

Q(M)=Q(M)+RAT*(Q(M-1)-Q(M))

T(M)=T(M)+RAT*(T(M-1)-T(M))

R(M)=R(M)+RAT*(R(M-1)-R(M))

CALL PANDW(P(M),P(M-1),RAT,P(M),W(M),W(M-1),QHO,Q(M-1),Q(M),W(M))

1,IEQ,0)

TH(M)=TH(M)+RAT*(TH(M-1)-TH(M))

XMU(M)=XMU(M)+RAT*(XMU(M-1)-XMU(M))

GAM(M)=GAM(M)+RAT*(GAM(M-1)-GAM(M))

DO 605 J=1,NSP

605 ALP(J,M)=ALP(J,M)+RAT*(ALP(J,M-1)-ALP(J,M))

606 CONTINUE

A=.5

B=.5

GO TO 250

7520 CONTINUE

IF (IFENCE.EQ.0.OR.XN(1).NE.XCOWLH) GO TO 3108

XXP=(YN(L)-BFENCE)/AFENCE+XBP

IF (XN(L).LT.XXP) GO TO 520

DUM=(YN(L)-YN(K))/(XN(L)-XN(K))

XXP=(AFENCE*XBP-BFENCE-DUM*XN(K)+YN(K))/(AFENCE-DUM)

3108 CONTINUE

IF (XJ1.EQ.0..AND.IOVER.EQ.0) GO TO 520

IF (XN(L).LT.XXJ1(NXXJ).AND.XN(L).LT.XXP) GO TO 520

IF (LST.GT.0) GO TO 520

LST=1

XNN=XXP

IF (XN(L).GE.XXJ1(NXXJ)) XNN=XXJ1(NXXJ)

RAT=(XNN-XN(K))/(XN(L)-XN(K))
IAA=IAA+1
IF (IPP.GT.NPTS.OR.IAA.LT.IPP) GO TO 3999
WRITE(6,3998)

3998 FORMAT(* INDEXING IN CHANGE OF ORIGIN OVERLAPS INITIAL DATA IAA.EQ.
1UALS IPP*)
STOP

3999 XN(L)=XNN
YN(L)=YN(K)+RAT*(YN(L)-YN(K))
THN(L)=THN(K)+RAT*(THN(L)-THN(K))
DUM1=ALOG(PN(K))
DUM2=ALOG(PN(L))
DUM=DUM1+RAT*(DUM2-DUM1)
PN(L)=EXP(DUM)
IDPT=1

A=1.

B=0.

GO TO 253

8401 IDPT=0
IF (IFENCE.EQ.0.OR.XN(1).NE.XCOWLH) GO TO 9804
IF (IAA.LT.3.OR.XF(1).EQ.XFENCE) GO TO 9804
WRITE(6,9805)

9805 FORMAT(* FENCE MAY NOT BE ENTIRELY SUPERSONIC - CHECK FLOW FIELD*)
STOP

9804 CONTINUE

X F(IAA)=X N(L)
Y F(IAA)=Y N(L)
Q F(IAA)=Q N(L)
R F(IAA)=R N(L)
W F(IAA)=W N(L)
T F(IAA)=T N(L)
P F(IAA)=P N(L)
THF(IAA)=THN(L)
DO 8402 J=1,NSP

8402 ALPF(J,IAA)=ALPN(J,L)
IF (IAA.EQ.2.AND.LSTT.EQ.0) GO TO 520
LMAX=L
GO TO 265

520 CONTINUE

IF (XN(L).LT.XXJ1(NXXJ).AND.XN(L).LT.XXP) GO TO 5520
IF (LSTT.EQ.0) GO TO 5520
LMAX=L
GO TO 265

6520 CONTINUE

A=1.

B=0.

L=LMAX

KK=KMAX

K=LMAX-1

5011 CONTINUE

IF (B.EQ.0.) THN(L)=TH(KK)

IB=1

630 CONTINUE

EMSL=XM3(.5,.5,TH(KK),THN(L))
EM2=XM2(A,B,THN(K),XMUN(K),THN(L),XMUN(L))
IF (IDESGN.EQ.0.AND.IFLIP.NE.1)

1CALL BODL(X(KK),Y(KK),TH(KK),XN(K),YN(K),EM2,XN(L),YN(L),THN(L))

IF (IFLIP.NE.1) GO TO 631

XN(L)=(YN(K)-Y(KK)+EMSL*X(KK)-EM2*XN(K))/(EMSL-EM2)

YN(L)=Y(KK)+EMSL*(XN(L)-X(KK))

631 CONTINUE

```

B1=F1(A,B,XMUN(K),GAMN(K),PN(K),XMUN(L),GAMN(L),PN(L))
XDUMK=XN(K)-XOR(NXXJ-1)
XDUML=XN(L)-XOR(NXXJ-1)
B2=F2(A,B,-1.,XJ,XJ1,XDUMK,YN(K),THN(K),XMUN(K),XDUML,YN(L),THN(L),
1,XMUN(L))
DUM1=B2*(XN(L)-XN(K))
IF(XJ1.GT.0.)DUM1=B2*ALOG(XDUML/XDUMK)
DUM=(THN(L)-THN(K)-DUM1)/B1
PN(L)=PN(K)*EXP(DUM)
IF(B.EQ.0.) GO TO 1821
L1=LMAX
L2=KMAX
IF(XN(L1).GT.XXJ1(NXXJ-1).E-04) GO TO 1821
Z1=A XX(NXXJ-1)*(X(L2)-XBP)+B XX(NXXJ-1)
Z2=A XX(NXXJ-1)*(XN(L1)-XBP)+BX(X(NXXJ-1)
DA X=(Z1+Z2)/2.*ABS(YN(L1)-Y(L2))
DA Y=(Z1+Z2)/2.*(XN(L1)-X(L2))
PA V=(PN(L1)+P(L2))/2.
PA V=(PAV/PIN-1.)*PIN*144.
DX TH X=PA V*DA X
DYLFT=PAV*DAY
XMS=(XN(L1)+X(L2))/2.-XSHFT
YMS=(YN(L1)+Y(L2))/2.-YSHFT
DMOM=YMS*DXTX-XMS*DYLFT
XTHX=XTHX+DXTX
YLFY=YLFY+DYLFT
XMOM=XMOM+DMOM

```

1821 CONTINUE

```

DO 1503 J=1,NSP
ALPN(J,L)=ALP(J,KK)
1503 ALPDUM(J)=ALPN(J,L)
IF(I.EQ.1) GO TO 3004
TERM2=RH0(KK)*Q(KK)*A
IF(B.GT.0.) TERM2=TERM2+B*RHON(L)*QN(L)
QN(L)=(P(KK)-PN(L))/TERM2+Q(KK)
IF(S.EQ.0.) CPXN(L)=CPX(KK)
TN(L)=T(KK)+(QN(L)+Q(KK))*(PN(L)-P(KK))*EIN/(CPX(KK)+CPXN(L))/T
1ERM2

```

```

CALL ALL(CPXN(L),WN(L),RHON(L),RN(L),GAMN(L),EMN(L),XMUN(L),QN(L),
1,TN(L),PN(L),ALPDUM)
GO TO 3005

```

3004 CONTINUE

```

RHON(L)=RH0(KK)*(PN(L)/P(KK))*((1./GAM(KK))
VVL=Q(KK)*Q(KK)+2.*GAM(KK)/(GAM(KK)-1.)*(P(KK)/RH0(KK)-PN(L)/RH
1ON(L))

```

```

QN(L)=SQRT(VVL)
WN(L)=W(KK)+.5*(Q(KK)*Q(KK)-VVL)
RN(L)=R(KK)

```

```

TN(L)=FT(PN(L),RN(L),WN(L))

```

```

GAMN(L)=FGAM(TN(L),PN(L),RN(L))

```

```

EMN(L)=QN(L)/SQRT(GAMN(L)*PN(L)/RHON(L))

```

```

XMUN(L)=ATAN(1./SQRT(EMN(L)*#2-1.))

```

3005 CONTINUE

```

IF(IFLIP.NE.1) GO TO 632

```

```

P2=PN(L)/P(KK)

```

```

CALL PM(P2,TH(KK),EMC1,TH2T,EMC2,+1)

```

```

ER4=TH2T-THN(L)

```

```

IF(ABS(ER4).LT.1.E-04) GO TO 632

```

```

IB=IB+1

```

```

IF (IB.GT.15) GO TO 633
IF (IB.GT.2) GO TO 634
ER6=ER4
THSVV=THN(L)
THN(L)=THN(L)-.01*ABS(THN(L))
GO TO 630
633 WRITE(6,635)
635 FORMAT(* ERROR IN PM LOOP AT CONTACT IN MAIN*)
STOP
634 DUM1=THSVV-ER6*(THN(L)-THSVV)/(ER4-ER6)
ER6=ER4
THSVV=THN(L)
THN(L)=DUM1
GO TO 630
632 CONTINUE
IF (B.GT.0.) GO TO 1265
A=.5
B=.5
GO TO 5011
1265 IAAS=IAA
IF (IFLIP.EQ.2.AND.XN(L).GE.XFINAL) IHALT=1
IF (IHALT.EQ.1) GO TO 1802
IF (XN(L).GE.XFINAL) GO TO 1802
IF (XJ1.EQ.0.AND.IOVER.EQ.0) GO TO 265
IF (IFENCE.EQ.0.OR.XN(1).NE.XC0WLH) GO TO 3109
IF (XN(L).LT.XFENCE) GO TO 265
XNN=XFENCE
GO TO 3110
3109 CONTINUE
IF (XN(L).LT.XXJ1(NXXJ)) GO TO 265
1802 CONTINUE
XNN=XXJ1(NXXJ)
3110 CONTINUE
RAT=(XNN-X(KK))/((XN(L)-X(KK)))
IAA=1
LSTT=1
XF(IAA)=XNN
IF (IFLIP.EQ.1) GO TO 2605
XCH=XNN-XINTL
LK=3
IF (XCH.LT.XXL(3)) LK=2
IF (XCH.LT.XXL(2)) LK=1
YF(IAA)=AA1(LK,2)*XCH*XCH+AA2(LK,2)*XCH+AA3(LK,2)
THF(IAA)=ATAN(2.*AA1(LK,2)*XCH+AA2(LK,2))
GO TO 2606
2605 YF(IAA)=Y(KK)+RAT*(YN(L)-Y(KK))
THF(IAA)=ATAN(TAN(TH(KK))+RAT*(TAN(THN(L))-TAN(TH(KK))))
2606 CONTINUE
QF(IAA)=Q(KK)+RAT*(QN(L)-Q(KK))
RF(IAA)=R(KK)+RAT*(RN(L)-R(KK))
PF(IAA)=P(KK)+RAT*(PN(L)-P(KK))
L1=IAA
L2=KMAX
Z1=A*XX(NXXJ-1)*(X(L2)-XBP)+B*XX(NXXJ-1)
Z2=A*XX(NXXJ-1)*(XF(L1)-XBP)+B*XX(NXXJ-1)
DAX=(Z1+Z2)/2.*ABS(YF(L1)-Y(L2))
DAY=(Z1+Z2)/2.*((XF(L1)-X(L2)))
PAV=(PF(L1)+P(L2))/2.
PAV=(PAV/PIN-1.)*PIN*144.
DXTHX=PAV*DAX

```

```

DYLFT = +PAV*DAY
XMS = (XN(L1)+X(L2))/2. - XSHFT
YMS = (YF(L1)+Y(L2))/2. - YSHFT
DMOM = YMS*DXTX - XMS*DYLFT
XTX = XTHX + DXTHX
YLF = YLF + DYLFT
XMOD = XMOM + DMOM

```

```

WF(IAA) = W(KK) + RAT*(WN(L) - W(KK))
TF(IAA) = T(KK) + RAT*(TN(L) - T(KK))
WA = W(KK) + Q(KK) * Q(KK) / 2.
IF (IEQ.EQ.1) WF(IAA) = WA - QF(IAA) * QF(IAA) / 2.
DO 3841 J=1,NSP

```

```

3841 ALPF(J,IAA) = ALP(J,KK) + RAT*(ALPN(J,L) - ALP(J,KK))
IAA = IAAS

```

```
265 CONTINUE
```

```
C IF (PN(LMAX),LE,PEN.AND.,IDESGN.EQ.1) GO TO 7634
```

```
KMAX = LMAX
```

```
BE = BE TN
```

```
EMC1 = EMC2
```

```
DO 270 K=1,KMAX
```

```
X(K) = XN(K)
```

```
Y(K) = YN(K)
```

```
Q(K) = QN(K)
```

```
T(K) = TN(K)
```

```
TH(K) = THN(K)
```

```
P(K) = PN(K)
```

```
R(N(K)) = R(N(K))
```

```
W(N(K)) = W(N(K))
```

```
CPX(K) = CPXN(K)
```

```
RHO(K) = RHON(K)
```

```
GAM(K) = GAMN(K)
```

```
EM(N(K)) = EM(N(K))
```

```
XMU(K) = XMUN(K)
```

```
DO 271 J=1,NSP
```

```
271 ALP(J,K) = ALPN(J,K)
```

```
DO 1504 J=1,NSP
```

```
1504 ALPDUM(J) = ALP(J,K)
```

```
CALL ALL(CPX(K),W(K),RHO(K),R(K),GAM(K),EM(K),XMU(K),Q(K),T(K),
1P(K),ALPDUM)
```

```
270 CONTINUE
```

```
7266 IF(N-NPTS) 7201,7202,500
```

```
7201 N=N+1
```

```
GO TO 500
```

```
7202 CONTINUE
```

```
NSTAR=1
```

```
IPPSV=IPP+1
```

```
N=N+1
```

```
GO TO 500
```

```
9123 KTEST=KMAX/2
```

```
KTEST1=(KMAX-1)/2
```

```
KT3=KMAX-1
```

```
IF(KTEST.EQ.KTEST1) KT3=KMAX
```

```
I=0
```

```
DO 6412 L=1,KT3,2
```

```
I=I+1
```

```
X(I)=X(L)
```

```
Y(I)=Y(L)
```

```
Q(I)=Q(L)
```

```
P(I)=P(L)
```

```
T(I)=T(L)
```

```
W (I)=W (L)
R (I)=R (L)
TH (I)=TH (L)
EM (I)=EM (L)
CPX(I)=CPX(L)
RHO(I)=RHO(L)
GAM(I)=GAM(L)
XMU(I)=XMU(L)
DO 6414 J=1,NSP
6414 ALP(J,I)=ALP(J,L)
6412 CONTINUE
IF (KTEST.EQ.KTEST1) GO TO 6413
I=I+1
L=KMAX
X (I)=X (L)
Y (I)=Y (L)
Q (I)=Q (L)
P (I)=P (L)
T (I)=T (L)
W (I)=W (L)
R (I)=R (L)
TH (I)=TH (L)
EM (I)=EM (L)
CPX(I)=CPX(L)
RHO(I)=RHO(L)
GAM(I)=GAM(L)
XMU(I)=XMU(L)
DO 6415 J=1,NSP
6415 ALP(J,I)=ALP(J,L)
6413 KMAX=KMAX/2+1
LMAX=KMAX
GO TO 6060
END
```

SUBROUTINE INDATA
COMMON/COWL/ICOWL,MM,XM(9),YM(9),PM(9),WM(9),RHM(9),THM(9),OM(9),
1RM(9),TM(9),GM(9),XMUM(9),EMM(9),ALPM(7,9),CPXM(9)

COMMON/SHAPE/ A1(3,2),A2(3,2),A3(3,2),XXU(3),XXL(3),XINTU,XINTL
COMMON/LTM/XSHFT,YSHFT,XTHX,YLFT,XMOM

COMMON/XXJ/NXXJ1,XXJ1(6),AXX(6),BXX(6),XOR(6)

COMMON/XFINAL/XFINAL

COMMON/SP/ NSP

COMMON/A/ TIN,CPIN,RO

COMMON/B/ WTMOLE

COMMON/D/ GAMINF,EMINF,RINF,WINF

COMMON/F/A9,B9,IBOD,XWF,NBOD,YEND

COMMON/ETX/XJ,XJ1,NPTS,IO,IREFL,ICHEM,IPUNCH,IDESGN,IR,NXX,XBP,
1YBP,THBP,RAD,XBOD,YBOD,TBOD,RADB,XEND,THEND,RTH,YEXIT,THST,TEST,
1IREFL,Y0,RA2DB2,RRAD(20),NSTAR,YN0Z,EIN,PEN,R16,H17

1IREFL,Y0,RA2DB2,RRAD(20),NSTAR,YN0Z,EIN,PEN,R16,H17
COMMON/XF/XF(200),YF(200),PF(200),QF(200),TF(200),THF(200),ALPF(10,200)

COMMON/X/X(200),Y(200),P(200),Q(200),T(200),TH(200),ALP(10,200)

COMMON/XCOWL/XCOWL

COMMON/FVAR/

1RHOF(200),CPXF(200),EMF(200),XMUF(200),WF(200),RF(200),GAMF(200),

2XMASF(200),HF(200),SF(200),ALPD(10),

3THETA(20)

COMMON/VAR/RHO(200),

1EM(200),XMU(200),CPX(200),W(200),R(200),GAM(200),XMASS(200),

2 XN(200),YN(200),QN(200),TN(200),PN(200),THN(200),RHON

3(200),EMN(200),XMUN(200),CPXN(200),WN(200),RN(200),GAMN(200),

4XMASSN(200),ALPN(10,200),SI(10),HI(10),ERR(20),TEMP(20)

5,ALPDUM(10)

COMMON/IEQ/IEQ,PIN,RHOINF,UINF,PINF

COMMON/I0VER/ I0VER

COMMON/XTJ1/XTJ1

COMMON/7FENCE/1FENCE,BFENCE,XFENCE

DI MENSION WTMOLE(10),TYPE(6),TYPE1(4),TYPE2(2),TYPE5(4),TYPE4(4)

DATA TYPE2/10H NOZZLE/,10HCENTERBODY/

DATA TYPE1/10H HYDROGEN A,10HHYDROCARBD,2H1R,5HN AIR/

DATA TYPE/10HTWO DIMENS,10HAXISYMMETR,10HLINE SOURCE,5HIONAL,5RIC

1,5HE /

DATA TYPE5/10HFL0W,10HDE S,9HFIELD,9HIGN/

DATA TYPE4/10HFROZEN,10HEQUILIBRIU,1H,1HM/

DATA XXU/3*1.E+06/,XXL/3*1.E+06/,END/1.E+06/

DATA I0VER/0/

400 FORMAT(1H1)

16 FORMAT(3X,I4,3X,10E12,4)

1602 FORMAT(10X,10E12.4)

IF(I0VER.EQ.2) GO TO 916

IO=0

IREFL=0

IPUNCH=0

IDESGN=0

ICHEM=0

READ(5,6895),J1,J2,NPTS,IEQ,ICOWL,I0VER

5100 NSP=7

6895 FORMAT(16I5)

READ(5,63) XBP,XBOD,XCOWL,RTH,TEST,XFINAL,XTJ1

READ(5,63) XSHFT,YSHFT,XTHX,YLFT,XMOM

READ(5,6895) NXXJ1

DO 9393 I=1,NXXJ1

9393 READ(5,9463) XXJ1(I),AXX(I),BXX(I),XOR(I)

```

9463 FORMAT(4E10.0)
  READ(5,4)  IFENCE,AFENCE,BFENCE,XFENCE
4 FORMAT(15.5X3E10.0)
  XXJ1(NXXJ1+1)=XFINAL
  AXX(NXXJ1+1)=AXX(NXXJ1)
  BXX(NXXJ1+1)=BXX(NXXJ1)
  XOR(NXXJ1+1)=XOR(NXXJ1)
  IF(IFENCE.EQ.0) GO TO 321
  XXJ1(NXXJ1+2)=XFINAL
  AXX(NXXJ1+2)=AXX(NXXJ1)
  BXX(NXXJ1+2)=BXX(NXXJ1)
  XOR(NXXJ1+2)=XOR(NXXJ1)
321 CONTINUE
  XINTU=XBP
  XINTL=XBOD
  READ(5,6895) NUWSEG,NLWSEG
  READ(5,6363) (XXU(L),A1(L,1),A2(L,1),A3(L,1),L=1,NUWSEG)
  READ(5,6363) (XXL(L),A1(L,2),A2(L,2),A3(L,2),L=1,NLWSEG)
6363 FORMAT(4E10.0)
3531 WRITE(6,7329) TYPE5(IDESGN+1),TYPE5(IDESGN+3)
7329 FORMAT(41X*N O Z Z L E - CENTER BODY //50XA10,A9)
  JP1=J1+1+2*J2
  JP2=JP1+3
  WRITE(6,7330) TYPE(JP1),TYPE(JP2),TYPE1(ICHEM+1)
  1,TYPE1(ICHEM+3),NPTS,RTH
7330 FORMAT(37X,*F0R N0NUNIFORM GAS FLOW
  2//10X,*TYPE OF FLOW IS *,A10,A5,* FOR *,
  3A10,A5/10X,*NUMBER OF POINTS ON INITIAL DATA LINE IS *,I3/10X,
  4*THROAT RADIUS (RTH) = *,E13.5)
  WRITE(6,5001) TYPE4(IEQ+1),TYPE4(IEQ+3)
5001 FORMAT(
  110X*CHEMISTRY IS *A10,A1)
  WRITE(6,7500) XCOWL,XFINAL
7500 FORMAT(10X*COWL TRAILING EDGE IS *E13.5/10X*AXIAL COORDINATE OF EN
  1D OF RUN IS *E13.5)
  IF(J2.EQ.0) GO TO 7510
  WRITE(6,7501) XTJ1
7501 FORMAT(10X*AXIAL COORDINATE OF START OF CARTESIAN SYSTEM IS *E13.5
  1)
  WRITE(6,7502)
7502 FORMAT(//25X*LINE SOURCE COORDINATES*)
  WRITE(6,7505)
  DO 7503 I=1,NXXJ1
7503 WRITE(6,7504) XXJ1(I),XXJ1(I+1),AXX(I),BXX(I),XOR(I)
7504 FORMAT(10X,4E11.3,5X,E11.3)
7505 FORMAT(15X*X*4X*T0*4X*X*11X*COORDINATES*12X*ORIGIN X*)
7510 CONTINUE
  WRITE(6,2020)
2020 FORMAT(//25X*UPPER WALL COORDINATES*)
  WRITE(6,2071)
2071 FORMAT(15X*X*4X*T0*4X*X*15X*COORDINATES*)
2042 FORMAT(10X,5E11.3)
  DO 2050 I=1,NUWSEG
  IF(I.EQ.3) GO TO 2051
  WRITE(6,2042) XXU(I),XXU(I+1),A1(I,1),A2(I,1),A3(I,1)
  GO TO 2050
2051 WRITE(6,2042) XXU(I),END ,A1(I,1),A2(I,1),A3(I,1)
2050 CONTINUE
  WRITE(6,2010)
2010 FORMAT(//25X*LOWER WALL COORDINATES*)

```

```

WRITE(6,2071)
DO 2040 I=1,NLWSSEG
IF(I.EQ.3) GO TO 2041
WRITE(6,2042) XXL(I),XXL(I+1),A1(I,2),A2(I,2),A3(I,2)
GO TO 2040
2041 WRITE(6,2042) XXL(I),END ,A1(I,2),A2(I,2),A3(I,2)
2040 CONTINUE
DO 7373 L=1,NLWSSEG
7373 XXU(L)=XU(L)-XINTU
DO 7374 L=1,NLWSSEG
7374 XXL(L)=XL(L)-XINTL
3532 CONTINUE
READ(5,63) EMINF,TIN,WINF,PINF
DO 5002 I=1,NPTS
DO 5002 J=1,NSP
5002 ALPF(J,I)=0.
READ(5,6364) (XF(I),YF(I),PF(I),QF(I),TF(I),THF(I),RF(I),I=1,NPTS)
IF(I.EQ.0.0)
1 READ(5,6364) ((ALPF(J,I),J=1,NSP),I=1,NPTS)
6364 FORMAT(7E10.0)
IF(ICOWL.EQ.1) READ(5,8698) MM, PM(MM),QM(MM),TM(MM),
1 THM(MM),RM(MM)
IF(I.EQ.0.OR.ICOWL.NE.1) GO TO 7512
WRITE(6,7512)
7512 FORMAT(* FROZEN EXTERNAL CASE NOT ALLOWED/* CHECK INPUT MANUAL FOR
1R POSSIBLE USES OF IEO AND ICOWL*)
STOP
7511 CONTINUE
8698 FORMAT(I5,5X,5E10.0)
IF(ICOWL.EQ.1) WRITE(6,5005)MM,PM(MM),QM(MM),TM(MM),THM(MM),RM(MM)
5005 FORMAT(//20X*DATA AT COWL*/10X*NUMBER OF POINTS IN PRANDTL-MEYER F
1AN IS *I2/10X*PRESSURE =*E13.5/10X*VELOCITY =*E
113.5/10X*TEMPERATURE =*E13.5/10X*FLOW INCLINATION =*E13.5/
110X*FUEL TO AIR RATIO =*E13.5)
IF(IREFL.EQ.0) GO TO 4000
916 CONTINUE
DO 4005 I=1,NPTS
II=NPTS-I+1
X(II)=XF(I)
Y(II)=-YF(I)
Q(II)=QF(I)
T(II)=TF(I)
P(II)=PF(I)
TH(II)=-THF(I)
R(II)=RF(I)
W(II)=WF(I)
DO 4010 J=1,NSP
4010 ALP(J,II)=ALPF(J,I)
4005 CONTINUE
DO 4006 I=1,NPTS
XF(I)=X(I)
YF(I)=Y(I)
QF(I)=Q(I)
TF(I)=T(I)
PF(I)=P(I)
THF(I)=TH(I)
RF(I)=R(I)
WF(I)=W(I)
DO 4007 J=1,NSP
4007 ALPF(J,I)=ALP(J,I)

```

```

4006 CONTINUE
  DUM=-YBP
  YBP=-YBOD
  YBOD=DUM
  DUM=-THBP
  THBP=-THBOD
  THBOD=DUM
  YEND=-YEND
  THEND=-THEND
  IF(I OVER.EQ.2) RETURN
4000 CONTINUE
  XJ=J1
  XJ1=J2
  WTMOLE(1)=1.008
  WTMOLE(2)=16.
  WTMOLE(3)=18.016
  WTMOLE(4)=2.016
  WTMOLE(5)=32.0
  WTMOLE(6)=17.008
  WTMOLE(7)=28.014
  WTMOLE(8)=44.011
  WTMOLE(9)=28.011
  WTMOLE(10)=44.1
  RO=1.987
  CALL COEFF(5,TIN,AZ,BZ,CZ,DZ,EZ,FZ,GZ)
  CPIN=(AZ+BZ*TIN+CZ*TIN**2+DZ*TIN**3+EZ*TIN**4)*RO/WTMOLE(5)
  CALL COEFF(7,TIN,AZ,BZ,CZ,DZ,EZ,FZ,GZ)
  CPII=(AZ+BZ*TIN+CZ*TIN**2+DZ*TIN**3+EZ*TIN**4)*RO/WTMOLE(7)
  RINF=RO/WINF
  CPIN=.232*CPIN+.768*CPII
  GAMINF=1./(1.-RINF/CPIN)
  EINF=(GAMINF-1.)*EMINF**2
  PIN=1./GAMINF/EMINF**2
  WRITE(6,6899) EMINF,TIN,WINF,PINF
6899 FORMAT(// 50X,*INFINITY CONDITIONS*50X,*-----*/
  1/40X,*MACH -----,E13.5/40X,*TEMPERATURE (DEGREES
  2 K) -----,E13.5/40X,*MOLECULAR WEIGHT -----,E13.5/40X
  1*PRESSURE (PSI) -----*E13.5)
  WRITE(6,6723)
6723 FORMAT(//40X,*OUTPUT VARIABLES ARE*40X,*NONDIMENSIONALIZED*/
  140X,*AS FOLLOWS --//40X,*X BY RTH*/40X,*Y BY RTH*/40X,*Q BY FREE S
  2STREAM VELOCITY*/40X,*T BY FREE STREAM TEMPERATURE*/40X,*P BY FREE
  3STREAM PRESSURE*)
  IF(I EQ.EQ.0) WRITE(6,5003)
5003 FORMAT( /40X,*ALP(J) IS MASS FRACTION OF SPECIES J*)
  DO 6897 I=1,NPTS
  PF(I)=PF(I)*PIN
6897 CONTINUE
  UINF=1716.*TIN*1.8/PIN
  RHOINF=(PIN/TIN/1.8/1716.)*2116.
  IF(I EQ.EQ.0) GO TO 2930
  DO 2929 I=1,NPTS
  2929 WF(I)=FH(PF(I),RF(I),TF(I))
2930 CONTINUE
  H16=GAMINF/WINF/2.*EMINF*EMINF
  H17=1./H16
  63 FORMAT(8E10,0)
  11 FORMAT(7E11.4)
  RETURN
  END

```

```

SUBROUTINE COEFF(I,T,A ,B ,C ,D ,E ,F ,G )
TM=1000
IF (T-1000)10,10,20
10 GO TO (15,16,13,11,12,17,14,18,19),I
11 A = 2.8460849E 00
B = 4.1932116E-03
C = -9.6119332E-06
D = 9.5122662E-09
E = -3.3093421E-12
F = -9.6725372E 02
G = -1.4117850E 00
GO TO 40
12 A = 3.7189946E 00
B = -2.5167288E-03
C = 8.5837353E-06
D = -8.2998716E-09
E = 2.7082180E-12
F = -1.0576706E 03
G = 3.9080704E 00
GO TO 40
13 A = 4.1565016E 00
B = -1.7244334E-03
C = 5.6982316E-06
D = -4.5930044E-09
E = 1.4233654E-12
F = -3.0288770E 04
G = -6.8616246E-01
GO TO 40
14 A = 3.6916148E 00
B = -1.3332552E-03
C = 2.6503100E-06
D = -9.7688341E-10
E = -9.9772234E-14
F = -1.0628336E 03
G = 2.2874980E 00
GO TO 40
15 A = 2.5000000E 00
B = 0.0
C = 0.0
D = 0.0
E = 0.0
F = 2.5470497E 04
G = -4.6001096E-01
GO TO 40
16 A = 3.0218894E 00
B = -2.1737249E-03
C = 3.7542203E-06
D = -2.9947200E-09
E = 9.0777547E-13
F = 2.9137190E 04
G = 2.6460076E 00
GO TO 40
17 A = 3.8234708E 00
B = -1.1187229E-03
C = 1.2466819E-06
D = -2.1035896E-10
E = -5.2546551E-14
F = 3.5852787E 03
G = 5.8253029E-01
GO TO 40

```

```

18 A=2.1701
B=1.0378115E-02
C=-1.0733938E-05
D=6.3459175E-09
E=-1.6280701E-12
F=-4.8352602E+04
G=1.0664388E+01
GO TO 40
19 A=3.7871332
B=-2.1709526E-03
C=5.0757337E-06
D=-3.4737726E-09
E=7.7216841E-13
F=-1.4363508E+04
G=2.6335459
GO TO 40
20 GO TO (25, 26, 23, 21, 22, 27, 24, 28, 29), I
21 A = 3.0436897E 00
B = 6.1187110E -04
C = -7.3993551E -09
D = -2.0331907E -11
E = 2.4593791E -15
F = -8.5491002E 02
G = -1.6481339E 00
GO TO 40
22 A = 3.5976129E 00
B = 7.8145603E-04
C = -2.2386670E-07
D = 4.2490159E-11
E = -3.3460204E-15
F = -1.1927918E 03
G = 3.7492659E 00
GO TO 40
23 A = 2.6707532E 00
B = 3.0317115E -03
C = -8.5351570E -07
D = 1.1790853E -10
E = -6.1973568E -15
F = -2.9888994E -04
G = 6.8838391E 00
GO TO 40
24 A = 2.3545761E 00
B = 1.5976316E -03
C = -6.2566254E -07
D = 1.1315849E -10
E = -7.6897070E -15
F = -8.9017445E +02
G = 6.3902879E 00
GO TO 40
25 A = 2.5000000E 00
B = 0.0
C = 0.0
D = 0.0
E = 0.0
F = 2.5470497E 04
G = -4.6001096E -01
GO TO 40
26 A = 2.5372567E 00
C = -8.8017921E -09
D = 5.9643621E -12

```

E = -5.5743608E-16
F = 2.9230007E 04
G = 4.9467942E 00

GO TO 40

27 A = 2.8895544E 00
B = 9.9835061E -04
C = -2.1879904E -07
D = 1.9802785E -11
E = -3.8452940E -16
F = 3.8811792E 03
G = 5.5597016E 00

GO TO 40

28 A= 4.4129266
B= 3.1922896E -03
C= -1.297823E -06
D= 2.4147446E -10
E= -1.6742986E -14
F= -4.8944043E +04
G= -7.2875769E -01
GO TO 40

29 A= 2.9511519
B= 1.55255767E -03
C= -6.1911411E -07
D= 1.1350336E -10
E= -7.7882732E -15
F= -1.4231827E -04
G= 6.531445

40 RETURN

END

```
SUBROUTINE ERROR(IIII)
  WRITE(6,100) IIII
100 FORMAT(7H1ERROR=15)
  CALL EXIT
  RETURN
END
```

```

SUBROUTINE BODL(XI,YI,THI,XL,YL,EM2,XN,YN,THN)
COMMON/SHAPE/ A1(3,2),A2(3,2),A3(3,2),XXU(3),XXL(3),XINTU,XINTL
XI=XI-XINTL
XL=XL-XINTL
ICK=1
L=3
ASL=TAN(THI)
XN=(YI-YL+XL*EM2-XI*ASL)/(EM2-ASL)
5 IF(XN.LT.XXL(3)) L=2
IF(XN.LT.XXL(2)) L=1
YN=A1(L,2)*XN*XN+A2(L,2)*XN+A3(L,2)
YT=YL+(XN-XL)*EM2
ER=(YN-YT)
IF(ABS(ER).LT.1.E-04) GO TO 10
ICK=ICK+1
IF(ICK.LT.15) GO TO 3511
WRITE(6,3512)
3512 FORMAT(* TOO MANY ITERATIONS IN BODL *)
STOP
3511 IF(ICK.GT.2) GO TO 3513
ER1=ER
XSL1=XN
XN=1.01*XN
L=3
GO TO 5
3513 DUM=XSL1-ER1*(XN-XSL1)/(ER-ER1)
ER1=ER
XSL1=XN
XN=DUM
L=3
GO TO 5
10 THN=ATAN(2.*A1(L,2)*XN+A2(L,2))
XI=XI+XINTL
XL=XL+XINTL
XN=XN+XINTL
RETURN
END

```

```
SUBROUTINE BODU(X,Y,TH)
COMMON/SHAPE/ A1(3,2),A2(3,2),A3(3,2),XXU(3),XXL(3),XINTU,XINTL
X=X-XINTU
L=3
IF (X.LT.XXU(3)) L=2
IF (X.LT.XXU(2)) L=1
Y=A1(L,1)*X+A2(L,1)*X+A3(L,1)
TH=ATAN(2.*A1(L,1)*X+A2(L,1))
X=X+XINTU
RETURN
END
```

```

SUBROUTINE COWL(OF T)
COMMON/COWL/ICOWL,MM,XM(9),YM(9),PM(9),WM(9),RHM(9),THM(9),QM(9),
1RM(9),TM(9),GM(9),XMUM(9),EMM(9),ALPM(7,9),CPXM(9)
COMMON/IEQ/IEQ,PIN,RHOINF,U1INF,PINF
COMMON/VAR/RHO(200),
1EM(200),XMU(200),CPX(200),W(200),R(200),GAM(200),XMASS(200),
2XN(200),YN(200),QN(200),TN(200),PN(200),THN(200),RHON
3(200),EMN(200),XMUN(200),CPXN(200),WN(200),RN(200),GAMN(200),
4XMASN(200),ALPN(10,200),SI(10),HI(10),ERR(20),TEMP(20)
5,ALPDUM(10)
COMMON/SP/NSP
COMMON/X/X(200),Y(200),P(200),Q(200),T(200),TH(200),ALP(10,200)
XM(MM)=X(1)
YM(MM)=Y(1)
PM(MM)=PM(MM)*PIN
WM(MM)=FH(PM(MM),RM(MM),TM(MM))
DO 4385 J=1,NSP
4385 ALPDUM(J)=0.
CALL ALL(QQ,WM(MM),RHM(MM),RM(MM),GM(MM),EMM(MM),XMUM(MM),QM(MM),
1TM(MM),PM(MM),ALPDUM)
BET=(THM(MM)-OPT*XMUM(MM)+TH(1))*1.1
IT T=1
IF AN=MM-3
3 IT=1
II=MM-1
VT=QM(MM)*COS(BET-THM(MM))
U1=QM(MM)*SIN(BET-THM(MM))
U1=ABS(U1)
GM1=GM(MM)-1.
GP1=GM(MM)+1.
XM1=EMM(MM)*SIN(BET-THM(MM))
XMS=RHM(MM)*U1
IF (IT, EQ, 1) UM=U1*(GM1*X1+X1+2.)/GP1/X1/X1
7 RH2=XMS/UM
PM(I I)=XMS*(U1-UM)+PM(MM)
V1=QM(MM)*QM(MM)
V2=VT*VT+UM*UM
WM(I I)=WM(MM)+(V1-V2)/2.
RM(I I)=RM(MM)
RHM(I I)=RHEQ(WM(I I),PM(I I),RM(I I),TM(I I))
ER=RH2-RHM(I I)
IF (ABS(ER),LT,1.E-04) GO TO 9
IT=IT+1
IF (IT,GT,10) GO TO 100
IF (IT,GT,2) GO TO 11
ER2=ER
U2=UM
UM=UM*.99
GO TO 7
100 WRITE(6,200)
200 FORMAT(* ERROR IN HUGONIOT LOOP IN COWL*)
STOP
11 DUM2=U2-ER2*(UM-U2)/(ER-ER2)
ER2=ER
U2=UM
UM=DUM2
GO TO 7
9 THM(I I)=BET-ATAN(UM/VT)
QM(I I)=SQRT(V2)

```

```

XM(I I)=XM(MM)
YM(I I)=YM(MM)
GM(I I)=FGAM(TM(I I),PM(I I),RM(I I))
EMM(I I)=QM(I I)/SQRT(GM(I I)*PM(I I)/RHM(I I))
XMUM(I I)=ATAN(1./SQRT(EMM(I I)*2-1.))
THM(I I-1)=THM(I I)
GM(I I-1)=QM(I I)
PM(I I-1)=PM(I I)
WM(I I-1)=WM(I I)
RHM(I I-1)=RHM(I I)
RM(I I-1)=RM(I I)
TM(I I-1)=TM(I I)
XM(I I-1)=XM(I I)
YM(I I-1)=YM(I I)
GM(I I-1)=GM(I I)
EMM(I I-1)=EMM(I I)
XMUM(I I-1)=XMUM(I I)
DP=(P(1)-PM(I I))/FLOAT(IFAN-1)
II=1
XM(I I)=X(1)
YM(I I)=Y(1)
WM(I I)=W(1)
PM(I I)=P(1)
RH M(I I)=RHO(1)
GM(I I)=GAM(1)
QM(I I)=Q(1)
TH M(I I)=TH(1)
XMUM(I I)=XMU(1)
TM(I I)=T(1)
RM(I I)=R(1)
EMM(I I)=EM(1)
DO 12 LL=2,IFAN
N=LL
KK=N-1
XM(N)=XM(KK)
YM(N)=YM(KK)
PM(N)=PM(KK)-DP
ALNR=ALOG(PM(N)/PM(KK))
RHM(N)=ALOG(RHM(KK))+ALNR/GM(KK)
RHM(N)=EXP(RHM(N))
G=2.*GM(KK)/(GM(KK)-1.)
QM(N)=SQRT(QM(KK)*QM(KK)-G*(PM(N)/RHM(N)-PM(KK)/RHM(KK)))
WM(N)=WM(KK)+(QM(KK)*QM(KK)-QM(N)*QM(N))/2.
RM(N)=RM(KK)
TM(N)=FT(PM(N),RM(N),WM(N))
GM(N)=FGAM(TM(N),PM(N),RM(N))
EMM(N)=(QM(N)/SQRT(GM(N)*PM(N)/RHM(N)))
XMUM(N)=ASIN(1./EMM(N))
A1=.5*(GM(N)/SIN(XMUM(N))/COS(XMUM(N))+GM(KK)/SIN(XMUM(KK))/COS
1(XMUM(KK)))
THM(N)=THM(KK)+OPT*ALNR/A1
12 CONTINUE
ER4=THM(IFAN)-THM(IFAN+1)
IF(ABS(ER4).LT.1.E-04) GO TO 15
ITT=ITT+1
IF(ITT.GT.15) GO TO 102
IF(ITT.GT.2) GO TO 14
ER1=ER4
BET1=BET
BET=BET+.02

```

GO TO 3

102 WRITE(6,203)

203 FORMAT(* ERROR IN BETA LOOP IN COWL*)

STOP

14 DUM1=BET1-ER1*(BET-BET1)/(ER4-ER1)

ER1=ER4

BET1=BET

BET=DUM1

GO TO 3

15 CONTINUE

RETURN

END

```

SUBROUTINE COWLO(I,THM,EM,BET,PM)
COMMON/FVAR/
1RHOF(200),CPXF(200),EMF(200),XMUF(200),WF(200),RF(200),GAMF(200),
2XMASSF(200),HF(200),SF(200),ALPD(10),
3THETA(20)
COMMON/XF/XF(200),YF(200),PF(200),QF(200),TF(200),THF(200),ALPF(
110,200)
COMMON/D/ GAMINF,EMINF,RINF,WINF
COMMON/C/ EMC1,TC1,QC1
J=I+1
BET=THF(I)-XMUF(I)
BET=BET-.1*ABS(BET)
ITT=1
3 CONTINUE
CALL SHOCK(BET,QF(I),THF(I),GAMF(I),EMF(I),RHOF(I),PF(I),WF(I),
1RF(I),QF(J),THF(J),GAMF(J),EMF(J),RHOF(J),PF(J),WF(J),RF(J),
1TF(J),XMUF(J),-1.)
P2=PF(J)*GAMINF*EMINF*EMINF
P2=P2/PM
TH2=THF(J)
CALL PM(P2,THM,EM,TH2T,EM3,-1)
ER4=TH2T-TH2
IF (ABS(ER4).LT.1.E-04) GO TO 15
ITT=ITT+1
IF (ITT.GT.15) GO TO 102
IF (ITT.GT.2) GO TO 14
ER1=ER4
BET1=BET
BET=BET+.02
GO TO 3
102 WRITE(6,203)
203 FORMAT(4 ERROR IN BETA LOOP IN COWLO*)
STOP
14 DUM1=BET1-ER1*(BET-BET1)/(ER4-ER1)
ER1=ER4
BET1=BET
BET=DUM1
GO TO 3
15 CONTINUE
DO 300 JJ=1,7
300 ALPF(JJ,J)=ALPF(JJ,I)
XF(J)=XF(I)
YF(J)=YF(I)
EMC1=EM3
DUM1=1.+ (GAMINF-1.)/2.*EMINF*EMINF
DUM2=1.+ (GAMINF-1.)/2.*EM3*EM3
TC1=DUM1/DUM2
QC1=EM3/EMINF*SQRT(TC1)
RETURN
END

```

```

SUBROUTINE SHOCK(BET,Q1,TH1,G1,EM1,RH1,P1,H1,PHI1,Q2,TH2,G2,EM2,
1RH2,P2,H2,PHI2,T2,XMU2,FSH)
1T=1
VT=Q1*COS(BET-TH1)
U1=ABS(Q1*SIN(BET-TH1))
GM1=G1-1.
GP1=G1+1.
XM1=EM1*SIN(BET-TH1)
XMS=RH1*U1
IF (IT.EQ.1)UM=U1*(GM1*XM1*XM1+2.)/GP1/XM1/XM1
7 RH2=XMS/UM
P2=XMS*(U1-UM)+P1
V1=Q1*Q1
V2=VT*VT+UM*UM
H2=H1+(V1-V2)/2.
PH12=PHI1
RH2T=ER*H2,P2,PHI2,T2)
ER=RH2-RH2T
IF (ABS(ER/RH1).LT.1.E-03) GO TO 9
IT=IT+1
IF (IT.GT.15) GO TO 100
IF (IT.GT.2) GO TO 11
ER2=ER
U2=UM
UM=UM*.99
GO TO 7
100 WRITE(6,200)
200 FORMAT(* ERROR IN HUGONIOT LOOP IN SHOCK*)
STOP
11 DUM2=U2-ER2*(UM-U2)/(ER-ER2)
ER2=ER
U2=UM
UM=DUM2
GO TO 7
9 IF (FSH.GT.0.) TH2=BET-ATAN(UM/VT)
IF (FSH.LT.0.) TH2=ATAN(UM/VT)+BET
Q2=SQR(T(V2))
G2=FGAM(T2,P2,PHI2)
EM2=Q2/SQR(T(G2+P2/RH2))
XMU2=ATAN(1./SQR(EM2*EM2-1.))
RETURN
END

```

```

SUBROUTINE SHOCPT( IS, M, BET, BETN, A, B)
COMMON/VAR/RHO(200),
1 EM(200), XMU(200), CPX(200), W(200), R(200), GAM(200), XMASS(200),
2 XN(200), YN(200), QN(200), TN(200), PN(200), THN(200), RHON
3 (200), EMN(200), XMUN(200), CPXN(200), WN(200), RN(200), GAMN(200),
4 XMASN(200), ALPN(10,200), SI(10), HI(10), ERR(20), TEMP(20)
5, ALPDUM(10)
COMMON/X / X(200), Y(200), P(200), Q(200), T(200), TH(200), ALP(10,200)
COMMON/E TX / XJ, XJ1, NPTS, ID, TREFL, ICHEM, IPUNCH, IDESGN, IR, NXX, XBP,
1 YBP, THBP, RAD, XBOD, YBOD, THBOD, RADB, XEND, THEND, RTH, YEXIT, THST, TEST,
1 IREFL, Y0, RADB2, RRAD(20), NSTAR, YNOZ, EIN, PEN, H16, H17
IF(B.EQ.0.) BETN=BET+(THN(IS-1)+XMUN(IS-1)-TH(M-1)-XMU(M-1))
I=IS
J=IS+1
L=IS
ITT=1
3 CALL SHOCK(BETN, QN(I), THN(I), GAMN(I), EMN(I), RHON(I), PN(I), WN(I),
1 RN(I), QN(J), THN(J), GAMN(J), EMN(J), RHON(J), PN(J), WN(J), RN(J), TN(J),
1 XMUN(J), 1.)
EM1=XM1(.5,.5, THN(J), XMUN(J), TH(M), XMU(M))
EM2=XM2(.5,.5, TH(M), XMU(M), TH(M+1), XMU(M+1))
YDUM=(EM1*Y(M)-EM2*YN(L)+EM1*EM2*(XN(L)-X(M)))/(EM1-EM2)
RAT=(YDUM-Y(M))/(Y(M+1)-Y(M))
Y2=YDUM
IF(IS.EQ.2.AND.M.EQ.2) RAT=0.
IF(IS.EQ.2.AND.M.EQ.2) Y2=Y(M)
X 2=X (M)+RAT*(X (M+1)-X (M))
CALL PANDW(P(M), P(M+1), RAT, P2, DUM1, DUM2, DUM3, DUM4, DUM5, DUM6, DUM7
1,1)
TH 2=TH (M)+RAT*(TH (M+1)-TH (M))
XMU2=XMU(M)+RAT*(XMU(M+1)-XMU(M))
GAM2=GAM(M)+RAT*(GAM(M+1)-GAM(M))
A1=F1(A, B, XMU2, GAM2, P2, XMUN(J), GAMN(J), PN(J))
A2=F2(A, B, 1., XJ, XJ1, X2, Y2, TH2, XMU2, XN(J), YN(J), THN(J), XMUN(J))
DUM1=A2*(XN(J)-X2)
DUM=(TH2-THN(J)-DUM1)/A1
PTEST=P2*EXP(DUM)
ER4=(PTEST-PN(J))/P(M)
IF(ABS(ER4).LT.1.E-04) GO TO 15
ITT=ITT+1
IF(ITT.GT.15) GO TO 102
IF(ITT.GT.2) GO TO 14
ER1=ER4
BET1=BETN
BETN=BETN+.02
GO TO 3.
102 WRITE(6,203)
203 FORMAT(* ERROR IN BETA LOOP IN SHOCPT*)
STOP
14 DUM1=BET1-ER1*(BETN-BET1)/(ER4-ER1)
ER1=ER4
BET1=BETN
BETN=DUM1
GO TO 3
15 CONTINUE
XN(J)=XN(I)
YN(J)=YN(I)
DO 300 JJ=1,7
300 ALPN(JJ,J)=ALPN(JJ,I)

```

RE TURN
END

```
SUBROUTINE PANDW(P1,P2,RAT,POUT,W1,W2,Q1,Q2,Q3,WOUT,IEQ,I)
DUM1=ALOG(P1)
DUM2=ALOG(P2)
POUT=DUM1+RAT*(DUM2-DUM1)
POUT=EXP(POUT)
IF (I.EQ.1) RETURN
WT1=W1+Q1*Q1/2.
WT2=W2+Q2*Q2/2.
WT3=WT1+RAT*(WT2-WT1)
WOUT=W1+RAT*(W2-W1)
IF (I.EQ.1) WOUT=WT3-Q3*Q3/2.
RETURN
END
```

```
SUBROUTINE DRTEST(XN,YN,EM1,BET, IDROP,L,M)
COMMON/X/ X(200),Y(200),P(200),Q(200),T(200),TH(200),ALP(10,200)
EM2=TAN(BET)
XNT=(Y(M)-Y(M+L)-EM1*X(M)+EM2*X(M+L))/(EM2-EM1)
YNT=Y(M)+EM1*(XNT-X(M))
DISNOR=SQR(T((XN-X(M))**2+(YN-Y(M))**2))
DISEX=SQR(T((XNT-X(M))**2+(YNT-Y(M))**2))
IF((DISEX-DISNOR)/DISEX.LT..1) IDROP=1
RETURN
END
```

```
SUBROUTINE PM(P, TH1, XM1, TH2, XM2, IS)
COMMON/D/ GAMINF, EMINF, RINF, WINF
G=GAMINF
GM1=G-1.
GP1=G+1.
DUM=1.+GM1/2.*XM1*XM1
P=P**(GM1/G)
XM2=(DUM/P-1.)*2./GM1
XM2=SQRT(XM2)
GX=SQRT(GP1/GM1)
DUM1=SQRT(XM1*XM1-1.)
DUM2=SQRT(XM2*XM2-1.)
DTH=GX*(ATAN(DUM2/GX)-ATAN(DUM1/GX))+ATAN(DUM1)-ATAN(DUM2)
TH2=TH1+FLOAT(IS)*DTH
RETURN
END
```

```
SUBROUTINE ALL (CPX,W,RHO,R,GAM,EM,XMU,Q,T,P,ALP1)
COMMON /IEQ/IEQ,PIN,RHOINF,UINF,PINF
COMMON /A/ TIN,CPIN,R0
COMMON /D/ GAMINF,EMINF,RINF,WINF
COMMON /B/ WTMOLE
COMMON /SP/ NSP
COMMON /ENTH/ HX
DIMENSION H1(10),CP1(10),DCP1(10),ALP1(10)
DIMENSION WTMOLE(10)
CPX=0.
IF (IEQ.EQ.1) GO TO 69
W=0.
HX=0.
CALL THERMO(T,H1,CP1,DCP1)
DO 10 J=1,NSP
CPX=CPX+ALP1(J)*CP1(J)
HX=HX+ALP1(J)*H1
10 W=W+ALP1(J)/WTMOLE(J)
W=1./W
RHO=GAMINF*EMINF**2*W*P/T/WINF
R=R0/W
GAM=CPX/(CPX-R/CPIN)
EM=Q*EMINF*SQRT(GAMINF*RINF/GAM/R/T)
XMU=ATAN(1./SQRT(EM**2-1.))
RETURN
69 RHO=RHEO(W,P,R,T)
GAM=FGAM(T,P,R)
EM=Q/SQRT(GAM*P/RHO)
XMU=ATAN(1./SQRT(EM*EM-1.))
RETURN
END
```

```
SUBROUTINE THERM(TI,H,CP,DCP)
COMMON /SP/ NSP
COMMON /A/ TIN,CPIN,RO
COMMON /B/ WTMOLE
DIMENSION WTMOLE(10)
DIMENSION H(10),CP(10),DCP(10)
T=TI*TIN
C1=RO/CPIN
C2=C1/TIN
C3=C1*TIN
N=NSP
DO 10 J=1,N
H1=C2/WTMOLE(J)
H2=C1/WTMOLE(J)
H3=C3/WTMOLE(J)
CALL COEFF(J,T,A,B,C,D,E,F,G)
H(J)=T*(A+T*(B/2.+T*(C/3.+T*(D/4.+E/5.*T))))+F
H(J)=H(J)*H1
CP(J)=A+T*(B+T*(C+T*(D+E*T)))
CP(J)=CP(J)*H2
DCP(J)=B+T*(2.*C+T*(3.*D+4.*E*T))
DCP(J)=DCP(J)*H3
10 CONTINUE
RETURN
END
```

```

FUNCTION FT(P1,F,H5)
COMMON/IPP/IPP
COMMON /THE/ A1,A2,A3,A4,A5,A6,XMM1
COMMON/IEQ/IEQ,PIN,RHOINF,UINF,PINF
COMMON/A/ TIN,CPIN,RO
DATA I 63/0/
IF LA G=0
IHOLD=0
P= P1 /PIN*PIN*1.01325E+05
H= H5 *UINF/10.7639/1.E+06
F2=F*F
A10=ALOG(P)/2.3-5.
Z9=.125*A10*A10 -.275*A10
IT=1
IF (I 63.EQ.1) GO TO 1000
I63=1
T=15.00.
T0=15.0.
IF (F.GE.0.) GO TO 120
T=60.0.
T0=T
1000 CONTINUE
IF (F.LT.0.) GO TO 400
GO TO 120
50 E0=(H-H1)/H
IF (ABS(E0).LT.1.E-04) GO TO 340
500 T=T0*1.1
502 IT=2
IF (F.LT.0.) GO TO 400
GO TO 120
100 E1=(H-H1)/H
IF (ABS(E1).LT.1.E-04) GO TO 340
IT=IT+1
IF (IT.LT.21) GO TO 10
IF (ABS(T-2000.).LT.10.) GO TO 830
IF (IHOLD.EQ.0) GO TO 800
WRITE(6,831) P1,H5,T
831 FORMAT(* ERROR IN FT*/* P1 = *E13.5,5X,*H1 = *E13.5,5X,*T = *E13.5
1)
STOP
800 T=THOLD
T0=T
H=HHOLD
IT=1
IHOLD=1
IF (T.LE.2000.) IHOLD=-1
GO TO 1000
830 IF (IFLAG.EQ.1) GO TO 504
IFLAG=1
T0=2000.
T=2000.
IF (F.LT.0.) GO TO 400
GO TO 120
504 WRITE(6,11) E1
11 FORMAT(* TEMPERATURE IN FT SET TO 2000 * - * ERROR = *E13.5)
GO TO 340
10 T9=T0-E0*(T-T0)/(E1-E0)
505 E0=E1
T0=T

```

T= T9

IF (F.LT.0.) GO TO 400

120 A= 1.E-07*(-.1042*F2 + .8242*F+.987)

B= .001*(-.01167*F2 + .1503*F+.938)

C= -.0284*F2 + .6731*F+.4293

IF (F.LE.1.) GO TO 190

A= 1.E-07*(1.787*F2 - 5.48*F+5.4)

B= .001*(-.1867*F2 + 1.11*F+.176)

C= -.0933*F2 + 3.975*F-2.808

190 IF (T.LE.2000., AND. IHOLD.NE.1) GO TO 290

A= .000001*(1.792*F2 + .3983*F+.31)

B= .01*(-9.05*F2 - .07917*F+.245)

C= 10.86*F2 - .1183*F+.97

IF (F.LE.1.) GO TO 290

A= .000001*(4.81*F2 - 13.9*F+11.59)

B= .01*(-23.08*F2 + 66.82*F-52.61)

C= 27.05*F2 - 73.73*F+58.39

290 H1 = A*T + B*T + C

IF (T.LE.2000., AND. IHOLD.NE.1) GO TO 370

H1 = H1*(1.+(1.+F)*(T/2000.-1.)*Z9)

370 CONTINUE

GO TO 350

400 T2 = T*T

T3 = T2*T

T4 = T3*T

T5 = T4*T

IF (F.LT.-1.5) GO TO 450

XMM1 = 16.043

A1 = 4.2497678

A2 = -6.9126562E-03

A3 = 3.1602134E-05

A4 = -2.9715432E-08

A5 = 9.5103580E-12

A6 = -1.0186632E+04

GO TO 460

450 CONTINUE

A1 = 1.1202436

A2 = 1.3905716E-02

A3 = 2.6568374E-06

A4 = -1.1560272E-08

A5 = 5.2386929E-12

A6 = 5.3328896E+03

XMM1 = 28.054

460 H1 = A1*T + A2*T2/2. + A3*T3/3. + A4*T4/4. + A5*T5 + A6

H1 = H1*XMM1/1.E+06

350 IF (IT.E0.1) GO TO 50

GO TO 100

340 T0 = T

FT = T/TIN

IHOLD = T

HHOLD = H

RETURN

END

```

FUNCTION FH(P1,F,T1)
COMMON /THE/ A1,A2,A3,A4,A5,A6,XMM1
COMMON/IEQ/IEQ,PIN,RHOINF,UINF,PINF
COMMON/A/ TIN,CPIN,RO

```

P=P1/PIN*PIN*1.01325E+05

T=T1*TIN

F2=F*F

IF(F.LT.0.) GO TO 400

IF(T.GT.2000.) GO TO 190

IF(F.GT.1.) GO TO 191

120 A=1.E-07*(-.1042*F2 + .8242*F+.987)

B=.001*(-.01167*F2 + .1503*F+.938)

C=-.0284*F2 + .6731*F+.4293

GO TO 290

191 A=1.E-07*(1.787*F2 - 5.48*F+.4)

B=.001*(-.1867*F2 + 1.11*F+.176)

C=-.0933*F2 + 3.975*F-2.808

GO TO 290

190 IF(F.GT.1.) GO TO 192

A=.000001*(1.792*F2 + .3983*F+.31)

B=.001*(-9.05*F2 -.07917*F+.245)

C=10.86*F2 -.1183*F+.97

GO TO 290

192 A=.000001*(4.81*F2 -13.9*F+11.59)

B=.001*(-23.08*F2 +66.82*F-52.61)

C=27.05*F2 -73.73*F+58.39

290 H1=A*T*T+B*T+C

IF(T.LE.2000.) GO TO 370

A10=ALOG(P)/2.3-5.

Z9=.125*A10*A10 -.275*A10

H1=H1*(1.+(1.+F)*(T/2000.-1.)*Z9)

370 H1=H1*1.E+06

GO TO 340

400 T2=T*T

T3=T2*T

T4=T3*T

T5=T4*T

H1=A1*T+A2*T2/2.+A3*T3/3.+A4*T4/4.+A5*T5+A6

H1=H1*8314.7XMM1

340 CONTINUE

FH=H1*10.7639/UINF

RETURN

END

FUNCTION FGAM(T1,P1,F)

```

COMMON /THE/ A1,A2,A3,A4,A5,A6,XMM1
COMMON/IEQ/IEQ,PIN,RHOINF,UINF,PINF
COMMON/A/ TIN,CPIN,RO

```

T=T1*TIN

T2=T*T

P=P1/PIN*PIN*1.01325E+05

XM=0.

IF(F.LT.0.) GO TO 550

IF(T.LE.1000.) GO TO 440

XM=-2.15E-08*T2 + .000091*T -.0695

440 XN=4.E-09*T2 -.00002*T -.019

IF(F.LE.1.) GO TO 470

XN=.0339*SQRT(T)-.000391*T -.681

470 G=-1.833E-07*T2 + .000075*T+1.367

IF(T.LT.500.) GO TO 520

G=2.E-08*T2 -.000138*T+1.423

1F(T,L1,2000,) GO TO 520

G=7.267E-08*T2 -.000457*T+1.85

520 G=GM*(ALOG(P)/2.3^5.)*XN*(F-1.)

GO TO 530

550 T3=T2*T

T4=T3*T

CP=A1+A2*T+A3*T2+A4*T3+A5*T4

G=CP*(CP-1.)

530 CONTINUE

FGAM=G

RETURN

END

```

FUNCTION RHEQ(H,P1,F,T)
COMMON/1EQ/1EQ,PIN,RH1INF,1INF,PINF
COMMON/A/ TIN,CPIN,RO
T1=FT(P1,F,H)
T=T1*TIN
P=P1/PIN*PIN* 1.01325E+05
IF(F.LT.0.) GO TO 2260
FM=1.53*F*F-5.895*F+28.965
FN=1.6*F*F-10.6*F+33.6
IF(T.GT.2000.) GO TO 2030
XM=FN
IF(F.LT.1.) GO TO 2160
XM=FN
GO TO 2160

```

```

2030 FF=F*F
A=-2.3*F*F+4.01*F+1.736
B=8.61*F*F-15.42*F-6.66
C=-16.88*F*F+33.21*F+14.58
XN=-.4375*FF+.0625*F+2.08
D=A*(ALOG(P)/2.3)**1.5+B*(ALOG(P)/2.3)+C
XM=FN-M*((T-2000.)/1000.)*XN
IF(F.LT.1.) GO TO 2160
A=-.822*FF+2.363*F+1.905
B=2.76*FF-7.56*F-8.68
C=-3.6*FF+7.36*F+27.15
XN=-.47*FF+1.825*F+.35
D=A*(ALOG(P)/2.3)**1.5+B*(ALOG(P)/2.3)+C
XM=FNN-M*((T-2000.)/1000.)*XN
GO TO 2160
2260 KF=F-.5
IF(KF.EQ.-1) XM=16.043
IF(KF.EQ.-2) XM=28.054
2160 RHEQ=P*XN/T/8314.3*6.2428E-02/32.174
T=T/TIN
RREQ=RHEQ/RH1INF
RETURN
END

```

```
FUNCTION XM1(ALPHA,BETA,TA,XA,TC,XC)
XM1=ALPHA*TAN(TA+XA)
IF(BETA.GT.0.)XM1=XM1+BETA*TAN(TC+XC)
RETURN
END
```

```
FUNCTION XM2 (AL,B,TA,XA,TC,XC)
XM2=AL*TAN(TA-XA)
IF (B.GT.0.)XM2=XM2+B*TAN(TC-XC)
RETURN
END
```

```
FUNCTION XM3(A,B,TD,TC)
XM3=A*TAN(TD)
IF(B.GT.0.0)XM3=XM3+B*TAN(TC)
RETURN
END
```

```
FUNCTION F1(A, B, XMU1, GAM1, P1, XMU2,  
1GAM2, P2)  
F1=SIN(XMU1)*COS(XMU1)/GAM1  
IF (B.GT.0.0)F1=(F1+SIN(XMU2)*  
1COS(XMU2)/GAM2 )/2.  
RETURN  
END
```

FUNCTION F2(A,B,OPT,XJ,XJ1,X,Y,TH,XMU,XN,YN,THN,XMUN)

F21=0.

IF(XJ.EQ.0.) GO TO 15

F21=A*SIN(TH)*SIN(XMU)/COS(TH+OPT*XMU)/Y

IF(B.GT.0.) F21=F21+B*SIN(THN)*SIN(XMUN)/COS(THN+OPT*XMUN)/YN

15 F22=0.

IF(XJ1.EQ.0.) GO TO 10

F22=A*COS(TH)*SIN(XMU)/COS(TH+OPT*XMU)

IF(B.GT.0.) F22=F22+B*COS(THN)*SIN(XMUN)/COS(THN+OPT*XMUN)

10 F2=F21+F22

RETURN

END

```

SUBROUTINE XMASSS(RATM,NPTS)
COMMON/FVAR/
1RHOF(200),CPXF(200),EMF(200),XMUF(200),WF(200),RF(200),GAMF(200),
2XMAS SF(200), HF(200),SF(200),ALPD(10),
3THETA(20)
COMMON/XF/XF(200),YF(200),PF(200),QF(200),TF(200),THF(200),ALPF(
110,200)
DO 170 I=1,NPTS
CALL FM (FM1,EMF(I),GAMF(I))
FM2=FM1/RATM
ITM=1
EMT=RATM*EMF(I)
197 CONTINUE
CALL FM(FMT,EMT,GAMF(1))
ERM=(FM2-FMT)/FM2
IF (ABS(ERM).LT.1.E-03) GO TO 171
DU MD=1./RATM
ITM=ITM+1
IF (ITM.GT.15) GO TO 2
IF (ITM.GT.2) GO TO 1
EMT1=EMT
ERM1=ERM
EMT=EMT+DU MD
GO TO 197
1 DU M=EMT1-ERM1*(EMT-EMT1)/(ERM-ERM1)
EMT1=EMT
ERM1=ERM
EMT=DU M
GO TO 197
2 WRITE(6,3)
3 FORMAT(* ERROR IN ITERATION LOOP IN XMASSS*)
STOP
171 CONTINUE
DUM=SQRT((GAMF(I)+1.)/(GAMF(I)-1.))
ET SQ=SQRT(EMT*EMT-1.)
ESQ=SQRT(EMF(I)*EMF(I)-1.)
XNU2=DUM*ATAN(ET SQ/DUM)-ATAN(ET SQ)
XNU1=DUM*ATAN(ESQ/DUM)-ATAN(ESQ)
DNU=XNU2-XNU1
CALL PHI(DNU,T)
170 CONTINUE
RETURN
END

```

SUBROUTINE FM(FMC,XM,G)
FMC=XM/(1.+(G-1.)/2.*XM**2)**((G+1.)/2./(G-1.))
RETURN
END

SUBROUTINE PM1(DNU,J6)

COMMON/FVAR/

1RHOF(200),CPXF(200),EMF(200),XMUF(200),WF(200),RF(200),GAMF(200),

2XMASF(200),HF(200),SF(200),ALPD(10),

3THETA(20)

COMMON/XF/XF(200),YF(200),PF(200),QF(200),TF(200),THF(200),ALPF(

110,200)

DTH=2./57.3

IFAN=DNU/DTH

IF(DTH.GE.DNU)DTH=DNU

IF(DTH.EQ.DNU)IFAN=1

P1=PF(J6)

T1=TF(J6)

EM1=EMF(J6)

H1=WF(J6)

G1=GAMF(J6)

RH1=RHOF(J6)

PHI1=RF(J6)

U1=QF(J6)

U1=U1*U1

HT=H1+U1/2.

P1=ALOG(P1)

XNU=0.

XNU1=0.

DO 10 I=1,IFAN

IF(I.EQ.1)DTH=DNU-XNU

XMU1=ASIN(1./EM1)

B1=G1*EM1/COS(XMU1)

P2=-B1*DTH+P1

RH2=(P2-P1)/G1

RH2=RH1*EXP(RH2)

P2P=EXP(P2)

P1P=EXP(P1)

U2=U1-2.*G1/(G1-1.)*(P2P/RH2-P1P/RH1)

H2=HT-U2/2.

T2=FT(P2P,PHI1,H2)

G2=FGAM(T2,P2P,PHI1)

A2=G2*P2P/RH2

EM2=SQRT(U2/A2)

XNU=XNU1+DTH

XNU1=XNU

P1=PF2

T1=TF2

G1=G2

EM1=EM2

U1=U2

RH1=RH2

10 CONTINUE

P2=EXP(F2)

U2=SQRT(U2)

P1F(J6)=P2

T1F(J6)=T2

GAMF(J6)=G2

EMF(J6)=EM2

Q1F(J6)=U2

RHOF(J6)=RH2

WF(J6)=H2

RETURN

END